THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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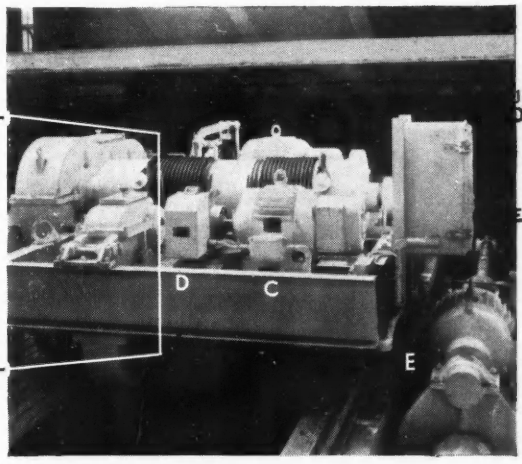
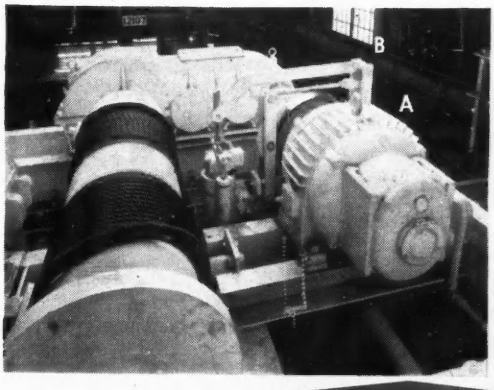
ON TOP OF THE JOB



Metrovick equipment is well on top in this 10-ton Wharton overhead shop crane. The hoist is an 18-h.p. 720 r.p.m. M-V motor fitted with a thrustor-operated brake giving precise control with stable creeping speed on load. The need for inching is thus eliminated. Drives for the long travel and cross-traverse are M-V 10-h.p. 715 r.p.m. and 3-h.p. 700 r.p.m. type MZ slipring motors respectively. A 6-inch Perigrip brake operates on the cross traverse. Write for details of the range of M-V a.c. and d.c. motors, control gear and Perigrip electromagnetic brakes for crane drives.



In the illustration (left) A is the 18-h.p. 720 r.p.m. hoist motor fitted with Stacreep thrustor control B. The long-travel drive, motor E, is shown at the top of page. The 3 h.p. cross traverse motor is seen at C and the 6-inch Perigrip brake at D.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *MEASUREMENT OF COMBUSTION-CHAMBER VOLUME*

The volume of the combustion chamber of an internal combustion engine cylinder or of carbon deposits can be measured with a high degree of accuracy by using air as the measuring medium. The idea of using air instead of liquid as a measuring fluid is not in itself new. The most recent innovation in this technique is the development of instruments which can measure volume by sensing an air pressure which is periodically varied in the combustion chamber. The frequency of oscillations is then compared with that of a known reference volume, so that the chamber volume can be deduced. In this method a jet of air or an acoustic transducer in the sparking-plug opening initiates air oscillation in the chamber. The sound is produced at 100 to 300 cps, depending on the throat dimensions and the chamber size. This sound is picked up by a microphone and is filtered, amplified, and shaped into a series of square voltage pulses. An electric counter then determines the number of pulses occurring in a given interval of time, and the measured resonant frequency is compared with that of a reference volume. It is stated that this sonic comparison under ideal conditions can sense volume changes of $\pm$ 0·02 cm³. Attention must be paid to the fact that a temperature sensitivity resulting in an error in volume of approximately 1 % exists for every 5° F difference between the combustion chamber and the reference chamber. In spite of the great potential accuracy of this method, the frequency shift caused by cylinder leakage and carbon deposits makes it difficult to determine the volume with an accuracy higher than 1 %. When the precise amount and density of carbon deposit is to be determined, pneumatic or static volume measurement is required.

● *EFFECT OF THE ROTATION OF THE EARTH ON LAMINAR FLOW*

A theory of laminar flow in pipes, which includes the effect of the rotation of the earth, has been propounded. It is shown that this effect depends on the component of the earth's rotation normal to the pipe, and is thus a maximum for flow in the east-west direction. Weak secondary circulations form in the cross-sectional plane. The intensity of these circulations, expressed non-dimensionally, is proportional to the ratio of the Reynolds number and the Rossby number. The cross circulations and the associated pressure field are extremely weak, even for flow at high Reynolds numbers. However, this flow tends to cause in the axial-flow distribution an asymmetry which can be significant, especially when the ratio of the square of the Reynolds number to the Rossby number exceeds 500. High velocities are displaced from the pipe axis in a direction specified by the negative cross product of the vectors parallel to the earth's axis and to the direction of fluid discharge. Laboratory experiments indicate the existence of such asymmetric flows. However, the measured asymmetry is about one-third of the theoretical value. This is attributed to the fact that the pipe system used was probably insufficient in length to allow the secondary flow associated with the earth's rotation to become fully established. Theory and experiment both indicate that, under certain conditions, the effect of the earth's rotation on pipe flow is not negligible. In particular, this factor may be of importance in the breakdown of laminar flow into turbulence at high Reynolds numbers.

● *INCREASING TAILSHAFT LIFE BY ROLLING*

A report has been issued which includes recommendations for the improvement in marine-propeller shaft life by means of surface rolling. About two years ago a series of reverse-bending fatigue tests on one-quarter scale models of tanker tailshaft propeller-hub assemblies was initiated. It was subsequently suggested by the investigators that surface rolling of the tailshaft would provide more resistance to fatigue in reverse bending than would attention to minor design details. The test programme was therefore expanded to include surface-rolled specimens. It is now reported that fourteen specimens were tested, of which six were of standard design, while four incorporated stress-relief modifications and four surface-rolled shafts in addition to the design modifications. The results were comparable with those obtained in railway-axle tests, the surface-rolled specimens all showing a marked improvement in resistance to fatigue failure. While the absolute degree of improvement could not be estimated, the investigators believe, from their studies of the tests in the light of the extensive work done in the railway-axle

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field, that greater fatigue resistance can be obtained in ship shaft installations by surface rolling. Their studies indicate that the incidence of fatigue failure may be expected to be lessened on a properly rolled surface, and that surface rolling will not eliminate cracks, but that their propagation will be greatly retarded, thus reducing the probability of complete failure. The depth of the cold-worked layer produced is dependent upon the geometry of the roller and shaft, the roller load, and the yield strength of the shaft material. The recommendations made express the fundamental relations existing between a roller and shaft.

● *HIGH-NITROGEN STEELS*

A new chronium-manganese steel with more than twice the usual maximum nitrogen content has been developed. This steel is reported to be completely austenitic at temperatures up to 2300° F and is considered to represent a new stainless steel with special applications, not merely a substitute material to be used during periods of nickel shortage, as was the original object. Nitrogen, of course, is known to be a powerful austenite stablizer, but its use in stainless steel had hitherto been limited to 0·25% or less, as greater nitrogen contents have been considered harmful because of their effects upon ingot soundness. It has, however, been found that, by adjusting the chemical composition, particularly the combined chromium and manganese contents, sound ingots can be produced with nitrogen contents as high as 0·65%. This discovery has paved the way to a new means of reducing nickel content. The first step was to vary the chromium, manganese, and nitrogen contents of the steel at low carbon and nickel levels, so as to establish the degree of the austenite stability at common rolling temperatures. Investigations made with different nickel percentages have shown that it is possible to produce a structure which is completely austenitic at 2300° F, with a chromium content of 17% and a residual nickel content in combination with a nitrogen content of 0·4% and a manganese content of 15%. The austenite field decreases and ferrite forms as the temperature is raised. For all the steels studied, it was found that increased manganese contents above a certain minimum level tended to promote ferrite rather than austenite at high temperatures.

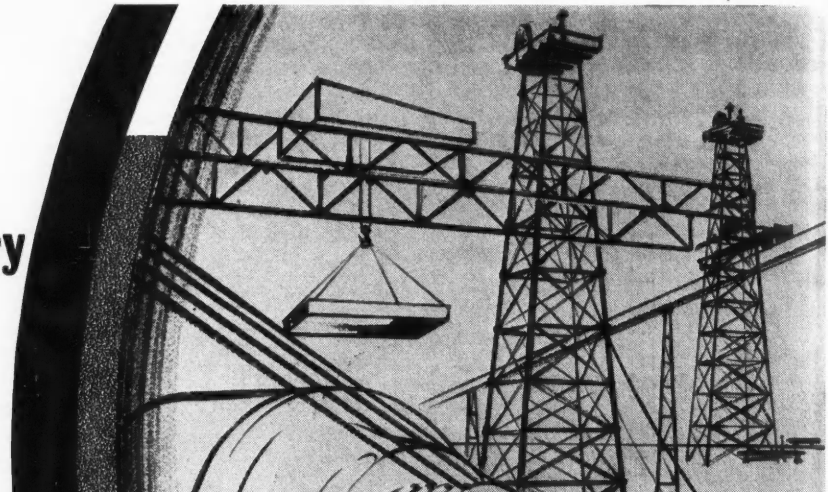
● *PURIFYING SEA WATER BY "ZONE REFINING"*

An investigation is now in progress to study the possibility of purifying sea water by " zone refining ", a term which has been borrowed from metallurgical practice, where it denotes utilization of the fact that metal impurities have different solubilities in solid and molten metal. This difference in solubility is used to remove impurities by moving a molten zone along a metal bar, sweeping, as it were, many impurities to the ends of the bar, and leaving the major portion of the bar purer than it was at the beginning of the process. It is believed that zone refining may be applicable to sea-water purification. In this case, a frozen, instead of a molten, zone would be used to sweep the natural salts through a column of sea water. Water reformed from ice after freezing would be pure enough for drinking and irrigation purposes if this method proves successful. From the scientific point of view, the method would have at least two advantages :—Firstly, it takes less energy to convert water into ice than it does to convert it into the steam needed in distillation processes, and secondly, since most natural sources of water are nearer to its freezing point than to its boiling point, less energy would be needed to move water through the shorter temperature range to its freezing point. It will be interesting, however, to see whether these advantages will outweigh the considerable mechanical energy requirements of the refrigeration cycle which will have to form part of the system.

● *AUTOMATIC HEADLIGHT SYSTEM FOR REDUCING GLARE*

In a new automobile headlighting system under development, instead of dipping and/or dimming headlights to reduce glare in the eyes of an approaching driver, a shadow is cast over that portion of the road which is occupied by oncoming cars, thereby leaving normal, long-range light on the lane in which the car is driving. One advantage is that the driver of a car equipped with the system can have visibility as good as or better than that obtained with present upper beams, though his headlamps will throw very little light towards the driver of the approaching car. It is anticipated that the seeing distance with the new headlamp will be about 500 to 1000 ft, even when meeting and passing an approaching car. This compares with a distance of 200 to 300 ft maximum—normally much less—obtained with the headlamps on low beam of current design. Development work is now focused upon the design and construction of an electrical system to control the position of the shadow in the opposite lane. When no car is approaching the lights cover a normal width. However, when a car appears in the opposite lane, a photosensitive cell reacts to the light from the headlight on the nearside of the oncoming car. As the car approaches, a vane moves in front of the cell, positioning itself in relation to the oncoming light. By electrical linkage a corresponding vane in the headlight is positioned to cast over the approaching car a shadow which changes position as the cars near each other. The system employs an ellipsoidal reflector, permitting a large shadow to be cast with a small, easily moved vane.

When industry gets tough Ferodo can take it



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● *CEMENTED OXIDE TOOLS*

It is claimed that cutting speeds in a range beyond even that of carbides can be achieved with cemented oxide tools. The composition and method of manufacture of the new material specifically developed for this purpose is not indicated in the original announcement, but it is known that refractory oxides with metal additions can be made by standard methods of powder metallurgy, sintered preferably in an oxidizing atmosphere. Generally, the functions of the metal additions are to promote bonding between the oxide particles and to increase both the thermal conductivity of the product and its resistance to thermal shock. According to initial tests, the cemented oxide tools may be used for finishing operations at the top-speed ranges of modern machine tools, and performance is said to be even better at speeds beyond 6000 fpm. Although no coolant is required, the tool may be used with coolants if heat deformation of the work is a factor to be considered. It is claimed that the tool material does not heat up and is generally cool to the touch following a machining operation. This is believed to be due to the fact that most of the heat is transferred to the chip and some to the work. When used with mechanical holders, tips of the new material can be used for the machining of nickel-chrome-molybdenum steels with hardnesses up to 300 Brinell. It is also claimed that the wear resistance of these tools is such that, in some tests, it indicated a tool life of more than 25 times that of carbides. It is expected that for finishing cuts the new tool will reduce cutting time drastically, as compared with carbides. The transverse rupture strength of the new material is stated to be 80,000 to 100,000 psi, presumably at room temperature, while the specific gravity is said to be 4·1 to 4·2, hardness being 93 to 94 Rockwell. Very good resistance to oxidation and corrosion is also claimed.

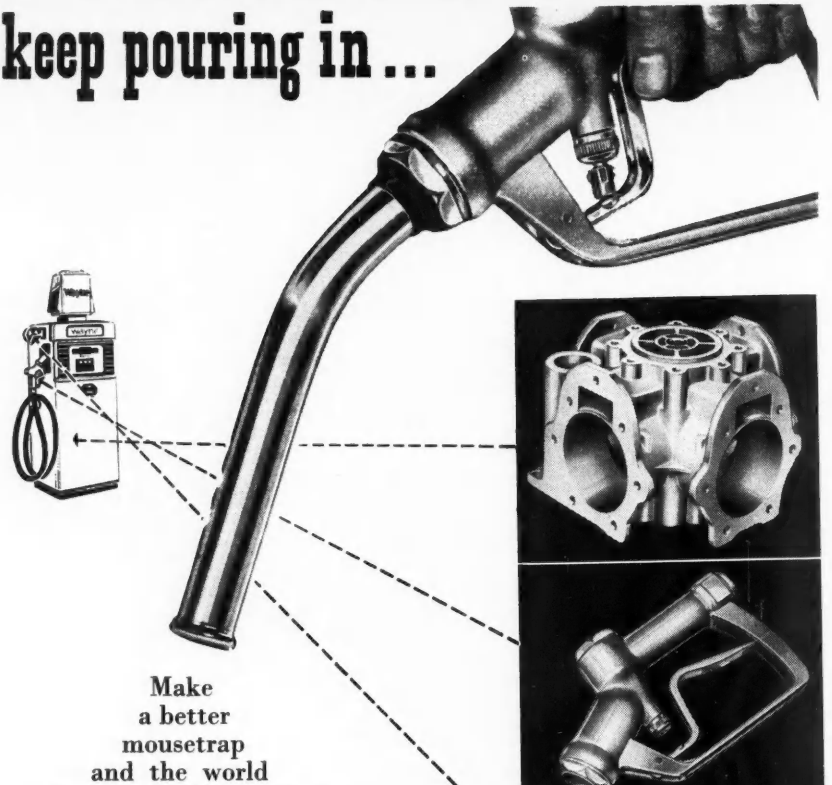
● *TEMPERATURE INDICATOR FOR JET ENGINES*

In the operation of jet engines precise indication of operating temperatures is a prerequisite to maximum thrust performance. A special temperature-indication system has recently been developed which replaces the galvanometer type of instrument for the measurement of exhaust-gas and turbine-inlet temperatures over the range of 200 to 1200° C. In principle the new instrument is similar to a laboratory type of potentiometer, such as that employed for high-precision temperature measurements, in which the output of a thermocouple is measured against an accurate reference voltage. A servo-driven self-balancing bridge is used to provide automatic, continuous comparison of these voltages and their translation into corresponding temperature indications. The indicator is helium-filled and is hermetically sealed. To prevent ambiguity during engine shutdown, the indicator is provided with a pointer stop which prevents downscale travel below the lower end of the scale. This stop is made to act in such a manner as to secure stalling of the servomotor, in order to prevent unnecessary gear action and wear. Temperature compensation of the thermocouple cold junction is accomplished by using a pair of resistors, one of which is sensitive and the other stable to temperature change. The voltage across the temperature-sensitive resistor is then determined by its temperature coefficient of resistance, which has been selected for close similarity to the output-versus-temperature curve of the thermocouple. Throughout the system precautions are taken to guard against the presence of secondary thermojunctions. At the amplifier input, thermocouple leads are brought to terminal studs made of the respective thermocouple materials. The compensating resistors, together with the thermocouple junctions and the voltage standard, are housed in a hermetically sealed silicone-oil thermal sink, which maintains all components at the same temperature.

● *PRESSURE SEALING OF BUNDLES OF ELECTRIC WIRE*

A novel method for the pressure sealing of wire bundles passing through bulkheads has been developed. It is considered that, although originally evolved for aircraft installations, this new sealing technique is applicable to the sealing of conduit, cable, and hydraulic lines passing through the walls between spaces maintained at different pressures. The method is based on the use of a cold-setting, non-adhesive thiokol material (polysulphide liquid polymer) to form the seal. A hollow plastic mould in the shape of a hemisphere, which is pierced and slit to receive the wire bundle, forms a mould cavity on each side of the bulkhead. The material selected for the semi-spherical moulds is cellulose acetate butyrate compounded to specific requirements with regard to clarity, shore hardness, and viscosity at the pour point. Permanent magnets, opposed to one another are incorporated into the mould, so that, when the hemispheres are split, the halves are self-aligning and magnetically attracted. This mould is then pierced at opposite sides to receive the wire bundle, and a small hole is made at the leading edge of the surface for effecting the injection of the sealing compound. The half-moulds are then threaded over each end of the wire bundle and brought together, held, and aligned by the permanent magnets. The thiokol is then injected by means of a pressure gun into the mould at one side until the material exudes from the hole at the other side. The sealant is then either air- or oven-cured, and when it is completely poly-

Orders keep pouring in...



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merized the moulds are removed. The result is a moulded-in-place rubber seal which overlaps the bulkhead hole and surrounds each wire of the bundle with a rubber sleeve. It is reported that seals of this type, approximately 2 in. in diameter, have been tested to 30 psi without leakage.

● *REDUCTION OF INTERIOR BEAD IN TUBE WELDING*

It is well known that the manufacturers of pipes and tubes have always had trouble with the weld bead on the inside diameter of welded tubing. By means of a fairly simple change in the welding process it has now been found possible to reduce the inside bead considerably and in some cases to eliminate it entirely. It is claimed that, without an interior bead, the tubing has better physical properties, improved corrosion resistance, and greater formability. The solution to the interior-bead problem reverses a basic practice in roll-formed tube weld practice, in that the tube is formed so that the seam is on the underside of the pipe as it leaves the rolls, and the weld is accomplished with the electrode positioned underneath the weld. The seam is joined by a standard butt weld, using the inert-gas-shielded tungsten-arc process. Because the weld is performed upside down, the metal does not flow into an interior bead. It is stated that the new welding system, in addition to controlling the interior bead, results in many improvements in tubing and pipe from both metallurgical and mechanical aspects. There is said to be a notable absence of grooves, valleys, or undercuts in the weld area after cold working or drawing. The outside-diameter weld bead can be held uniform and smooth, so that it is possible to reduce it by swaging and to improve its mechanical properties without undesirable side effects. Heavy-wall tubing and pipe will meet all mechanical tests such as flare, transverse, tensile, and reverse-bend tests. The tubing and pipe are said to have better fabrication properties in the production of tube assemblies, heat exchangers, condensers, and boilers. Furthermore, because of the smooth inside surface, many of the high alloys or super-alloys which previously required welding can now be rolled into tube sheets.

● *FIBRE METALLURGY*

To judge from a recent report, the new metal-felting technique termed "fibre metallurgy" should provide a promising production method for forming complex porous metallic shapes. The raw material for fibre metallurgy is wire from which the fibres or filaments are made by a shaving process, so that fairly continuous strands of metal can be formed. It is stated that control of fibre dimensions can be effected by adjustment of the planers which carry out the shaving. In felting, a suspension of the slurry metal fibre is in contact with a porous master pattern which is subjected to a vacuum. The liquid is drawn away through the master, on the surface of which a mat of fibre is left. One obvious advantage of this process is that the master can be of complex shape. Furthermore, considerable adjustment of the properties of the final product can be made by control of the fibre characteristics, such as length, diameter, kinking, surface roughness, etc. For example, by using fibres with a rough, barbed surface, mechanical interlocking of the fibres can be obtained, giving greater strength to low-density bodies. In addition, by producing a preferred orientation of the fibres, directional properties can be imparted and greater strength in a given direction can be achieved. For high-density parts the felted metal can be processed by passing it through rolls or by compressing it in dies in either single or multiple steps. In the form of sheet material the felted metal can be processed continuously by rolling, annealing, and sintering. Complex shapes can be compacted hydrostatically, using a rubber sac to exert pressure upon the part. Perhaps the most promising application of the material is its use for high-strength, high-porosity components and parts, since relatively high strength can be combined with a high degree of porosity.

● *PRACTICAL MAGNETIC REFRIGERATOR*

A new type of refrigerator has been developed which, it is claimed, will maintain lower temperatures than any previous apparatus, within a few tenths of a degree of absolute zero. The refrigerator is based on a cyclic principle of magnetic cooling and has no moving parts or fluids flowing in a cooling system. It embodies a plastic capsule, 3 in. in length, containing a special, undisclosed chemical salt as the refrigerant. Operation of the refrigerator is controlled by external magnetic fields. Magnetic cooling is based upon the fact that certain materials will warm up when magnetized and cool when demagnetized. The principle has been used for several years in a few laboratories for achieving extremely low temperatures in the range of absolute zero. It is claimed, however, that the new refrigerator is the first apparatus capable of producing these extremely low temperatures and maintaining them for long periods of time. It appears to represent the first commercial application of the phenomenon of superconductivity, i.e., the change which certain metals undergo at very low temperatures, when they lose all resistance to an electric current. At the same time, metals in a state of superconductivity act essentially as thermal insulators, although they are good conductors of heat when not showing the superconductivity effect.

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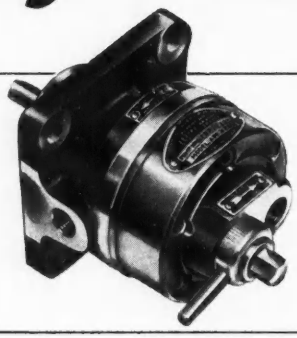

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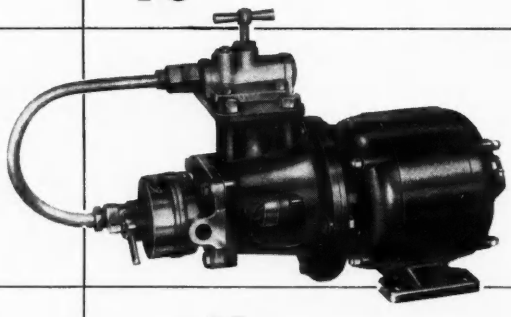

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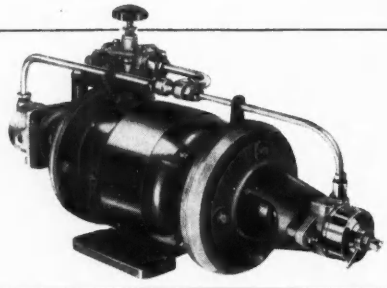

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REVIEW OF WORLD ENGINEERING PROGRESS

VOL XVII No. 1 JANUARY, 1956

Heavy-Press Plant for Large Structural Components of Aircraft

PLANNED and created to turn out vital structural members for high-speed aircraft, a " Heavy-Press Programme " has recently been established by the U.S. Air Force at its heavy-press plant, adjacent to the Cleveland, Ohio, plant of the Aluminum Company of America.

The core of the major forging facility at the plant, which comprises five main buildings, is a pair of what are claimed to be the world's largest presses, of 35,000 and 50,000 tons respectively (Fig. 1). The 35,000-ton press, shown in the foreground of the illustration, stands 42 ft above floor level and extends 34 ft below, while the 50,000-ton press in the background extends 50 ft above floor level and 36 ft below. The die-sinking shop of the plant (Fig. 2) is believed to be the largest ever built and includes giant furnaces for heating the massive billets required as forging stock, and a press, with a capacity of 2000 tons, for trimming flash from the forgings. The purpose of this combination of equipment is the production of major structural components of aircraft as single pieces of high-strength metal.

The entire plant, with a floor space of no less than 12 acres, has been built to support the operation of the two presses, and includes equipment for preparing the tremendous forging dies required, as well as the furnaces for heating the billets and for heat treatment of the forgings after hot working, and the necessary presses for straightening and trimming the forgings.

Fig. 1. **Heavy-press plant, showing (foreground) the 35,000-ton press, and (background) the 50,000-ton press.**

Production of the forgings commences with the pouring of the ingots. Four remelt furnaces, with a capacity of 40,000 lb, were installed in the ingot plant for melting scrap and pig. In addition, a new direct-chill ingot-casting unit is being installed, so as to permit the casting of more and larger ingots by a specially developed method. After casting, the ingots are cooled and dispatched to the nearby press plant on railway cars.

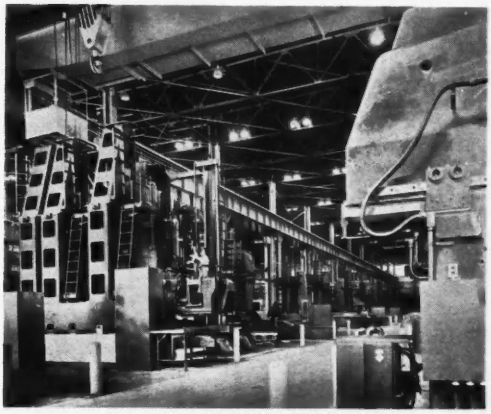

Fig. 2. **View of part of the die-sinking shop.**

In the metal preparation area the ingots are unloaded for the first step in forging production, which involves cutting the ingot or billet to size on large saws and, if necessary, executing some preliminary machining. Before sawing, all cast ingots are heated in a soaking furnace, after which their outer surfaces are machined away and they are carefully checked for soundness. After leaving this area, the billets are heated to closely controlled temperature limits before being subjected to the first forging operation. Each of the two large presses is supplied with heated billets by a battery of three continuous-heating, gas-fired furnaces, equipped with slat-type conveyor hearths and four controlled heat zones. As the heated billets emerge from the furnaces they are brought to the forging press by a manually controlled crane, or by mechanical manipulators designed to carry the billets to the bed of the press and place them in the forging dies.

Forging operations generally require at least two separate steps. Of these, the first is a blocking operation, which forms the metal in closed dies into the general shape of the forging. Fig. 3 shows a wing spar being removed from one of the presses after this blocking operation. The workman holding the long spray pipes is applying lubricant to the forging dies.

After blocking, the forging is subjected to process trimming, either with a saw or a trimming press. After surface defects have been removed, the forging is etched in large tanks, after which it is returned to the heating

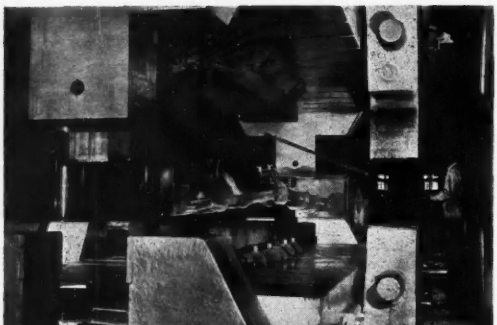

Fig. 3. A wing spar being removed from one of the presses after the blocking operation.

furnaces. One or possibly two additional forging operations are generally required to achieve the necessary high degree of precision, involving a finishing operation or possibly a second blocking operation, followed by finishing. Each operation normally requires a separate set of dies. After completion of the forging operations, the components are given a finish trim and etch, and are transferred to the heat-treatment department.

The plant is equipped for production solution heat-treating and ageing of the forgings. For this purpose four batch-type solution-treatment furnaces have been installed while, for artificial ageing, eight batch-type furnaces have been provided. This two-to-one ratio of ageing and solution-treating units arises from the fact that ageing requires approximately twice the time cycle as solution treatment, thereby permitting a continuous production cycle.

The solution-treating furnaces were constructed with the heating chamber directly over the quenching bath, thus allowing almost instantaneous quenching of the forgings. The components are loaded in the electrically heated solution-treating furnaces in alloy-steel trays and, after solution treatment has been completed, a transfer car picks up the trays of forgings and carries them directly into one of the gas-fired ageing furnaces.

After the completion of heat-treatment operations, the forgings are again etched. They are then subjected to final inspection for checking on quality and the final finishing operations, which may include straightening, ultrasonic testing, finish-grinding or machining, and final etching treatment. The forgings are then delivered to the shipping department for packaging and dispatch.

Approximately 3 acres of the total area in the new plant are devoted to the production of the necessary forging dies for the 50,000- and 35,000-ton presses. In this shop the closed-impression dies used are machined, the average set consisting of two die blocks, each of which may weigh as much as 25 tons. In the case of precision forgings, the die blocks may incorporate separately machined inserts for easy replacement of short-wear areas.

The machines used to mill these impressions include some of the largest of their kind, standing as high as 24 ft above floor level. One of these, to be installed shortly, is capable of machining a die block with a 10 × 28-ft face. Like the other twelve duplicating die-sinking machines in the shop, one of which is illustrated in Fig. 4, the new unit is a horizontal-spindle, tracer-controlled duplicating type. Using a plaster or wood model as a guide, these machines cut the forging impression into the steel die block. Other equipment involved in machining the dies includes a 10 × 40-ft planer ; a 130 in. × 13 ft × 30 ft and a 130 in. × 9 ft × 20 ft horizontal-spindle milling machine, and an 86-in. vertical boring mill.

After the rough impression has been machined in the die face, grinding and polishing of the dies to fine tolerances are carried out in a series of special booths, equipped with down-draught ventilation to carry away chips and dust. The dies are loaded on to mobile benches with an overhead crane, and the benches are then rolled into the booths.

The die-sinking shop also includes a department for the production of the plaster and wood forging-die patterns, and a small die heat-treating shop.

When a set of dies has been completed, it is loaded by an overhead crane on to a special 100-ton electrically operated transfer car, in which it is brought to the press bay of the main forging shop.

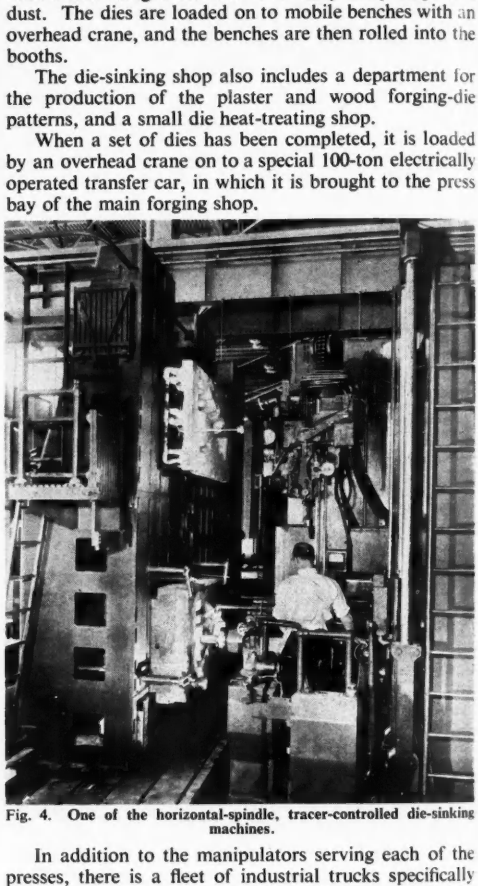

Fig. 4. One of the horizontal-spindle, tracer-controlled die-sinking machines.

In addition to the manipulators serving each of the presses, there is a fleet of industrial trucks specifically intended for keeping forgings moving continuously through the plant. In the main shop, there are seven major cranes and fifty-five smaller bridge-type cranes. Of the major cranes, the largest is a 200-ton unit serving the main press bay and intended for moving the die blocks to the presses and for lifting the heavy sections of the presses themselves during maintenance operations. Equipped with a 50-ton auxiliary hook, this crane has a span of nearly 100 ft and runs on a craneway 75 ft above floor level.

An elaborate system of quality control has been installed in the plant. Thus, for instance, a continuous check is made of forging temperature, while sample forgings are periodically examined during production. The accuracy of forging dimensions is checked in a special air-conditioned room.

A Simple Ultra-Microtome for Use in Electron Microscopy

By H. B. HAANSTRA. (From *Philips Technical Review*, Vol. 17, No. 6, December 1955, pp. 178–183, 9 illustrations.)

Owing to the very much higher resolving power of the electron microscope compared with the optical microscope, ultra-microtomes, capable of producing sections about 100 *times thinner than those of conventional microtomes, are required in electron microscopy. A simple, yet efficient, ultra-microtome for this purpose is described in this article.*

SPECIMENS which are to be studied in the microscope by transmitted light must be sufficiently transparent and must not contain too many discernible details behind each other in the direction of vision. The permissible thickness is thus related to the resolving power. For the optical microscope, with a resolving power of the order of 0·5 to 1 micron, specimens a few microns in thickness are required. Cutting such thin slices or sections of objects is an old technique, particularly for biological work and, with the present types of microtome, it is possible to make fairly reproducible sections of a thickness of a few microns, and in some cases of 1μ.

In the development of electron microscopy, an analogous problem has been met with from the outset. The image is formed in a somewhat different manner. Contrast occurs through the varying degree of electron scatter due to the varying density of the object ; moreover, the apertures of the incident beams are extremely small, so that there is a much greater depth of focus than in optical microscopy. The criteria for the permissible object thickness are, however, analogous with those for optical microscopes, i.e., the parts of the object in which details must be distinguishable, must transmit sufficient electrons of the energy employed (in most microscopes 50 to 100 keV), and there must not be too many details piled up behind each other. In view of the different manner of image formation the latter condition is even more important here than in optical microscopes ; in parts of the object lying behind others, the electrons may suffer repeated scattering, so that they "forget" the information which they should transmit and contribute only a general veil to the image. At worst, the detail looked for is obscured ; at best, the superimposed sharp images of details lying in different planes make interpretation more difficult.

Even for early electron microscopes, which reached a resolving power of a few hundred Ångstroms, sections of 1μ (10,000 Å) were much too thick. For a long time, therefore, research with the electron microscope was limited to objects which did not need cutting, e.g., very small isolated bodies or objects in the form of very thin films, or surfaces of which very thin replicas could be made. Innumerable techniques have been developed for this purpose and a great deal of research carried out in this way. In some fields, however, particularly anatomy and histology, no advantage could be taken of the high resolving power of electron microscopes, because their specimens cannot very well be prepared for investigation other than by making sections. With a resolving power of 50 Å, as quite normally attained in present electron microscopes, sections of a thickness of 200 Å or even less are needed.

Refinements of the classical microtome made possible sections of a thickness of 1000 Å, and in recent years Porter and others in America and Sjöstrand in Sweden have succeeded in constructing apparatus which will make sections of less than 200 Å in a reproducible manner. For the cutting of successive slices, of, for example, 100 Å thickness it is only reasonable to assume that ultra-microtomes should be instruments requiring the utmost precision in construction and should thus be rather costly. Surprisingly enough, however, it is possible to achieve this performance with a very simple instrument, the construction of which involves no exceptional precision work. A prototype of such an instrument is described in the following.

CONSTRUCTION OF THE NEW ULTRA-MICROTOME

The ultra-microtomes made by Porter, Sjöstrand, and others are distinguished from classical microtomes by the way in which the motion of the object is obtained. In the classical method, where the displacement is produced by a screw which causes the specimen holder to move along guides, the reproducibility is limited principally by the variation in thickness of the oil film between the moving surfaces requiring lubrication. This effect is entirely avoided in the ultra-microtomes of Porter and Sjöstrand by obtaining the displacement from the thermal expansion of a metal rod, at the end of which the specimen is mounted. Starting at room temperature and supplying heat at a constant rate, a very uniform, continuous change of length of the rod is obtained. If the extremity of the rod with the mounted specimen is then periodically allowed to carry out the cutting motion past the fixed knife, very thin sections of constant thickness are produced.

A complication occurs here, because the change of length is continuous. After a cut, the specimen has to be brought back to its original position with respect to the knife. Between the moment of cutting and that of return, the forward motion of the specimen has continued. The specimen may not, therefore, move back along the same path as it travelled in the cutting motion, since it would scrape along the knife and the surface of the next section would be destroyed before it was cut off. In one of the existing ultra-microtomes this problem was solved by mounting the object eccentrically on a vertical rotating disc. The specimen makes contact with the knife on the downward part of its path and not on the upward part. This construction, however, once more makes use of journal bearings, which threaten the reproducibility through their lubrication and possible vibration. To minimize this source of error the most extreme precision in finish was necessary.

In the new microtome described here the displacement is also obtained by thermal expansion. The return stroke, however, follows the same path as the cutting stroke, the necessary clearance between specimen and knife on the return journey being produced by magnetostriction. The rod on which the specimen is mounted is magnetized after each cutting stroke, before it moves upwards again ; the magnetization causes shrinkage, so that the specimen is pulled back slightly ; when it reaches the top position, the magnetic field is switched off and the rod reassumes exactly its original length—except for the thermal extension, which has continued in the meantime. The diagram in Fig. 1 illustrates schematically the successive motions, as follows :—

AB ≈ 1-2 μ:—Retraction by magnetostriction.

BC ≈ 3 mm :—Upward motion of specimen carrier.

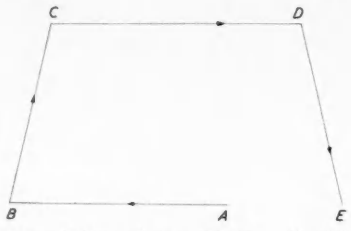

Fig. 1. Schematic diagram (not to scale) of the motion of the specimen in the new ultra-microtome.

$CD = AB$:—Magnetostriction released.

$DE = BC$:—Cutting stroke (specimen carrier drops).

The distance $AE \approx 50$ to 200 Å corresponds to the thermal expansion during the whole cycle *ABCDE*.

The whole arrangement now becomes extremely simple, because the same current is used to produce the gradual heating and the magnetostriction. The rod, the thermal expansion of which produces the displacement, is made of nickel, which exhibits a strong magnetostrictive effect. A coil is wound on the rod and through it flows an intermittent current of several amperes, which produces the periodic change of length, according to the diagram in Fig. 1. At the same time, the heat dissipated in the winding warms the rod to the desired degree. The intermittent supply of heat means that the distribution of temperature within the rod does not change uniformly throughout ; a slight ripple is superimposed on the heat passing into the rod. However, the thermal capacities of the system are so large that the resulting thermal expansion occurs uniformly with time.

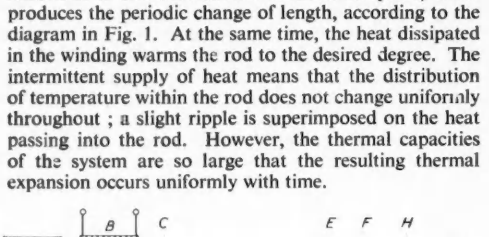

Fig. 2. Arrangement of the complete instrument.

It should be noted that in this instrument the unfavourable effects of lubricated bearings, sliding surfaces, etc. have been eliminated entirely, even in the up-and-down motion of the specimen. Instead of the more obvious hinged construction, use is made of a broad piece of spring strip ; the up-and-down movements are produced mechanically. Fig. 2 shows the arrangement of the whole instrument. The nickel rod or core *A*, surrounded by a coil *B*, produces the required displacement of the object by thermal expansion and periodic magnetostriction. The specimen *H* is mounted on a brass arm *E* of constant length, connected to the nickel rod by the spring strip *C*. The arm *E* carries near its free end a permanent magnet *F*, which is inserted into a vertically mounted solenoid *G*. An intermittent current is passed through the solenoid, forcing the magnet and the end of the arm upwards at intervals and then releasing them. During the downward movement the specimen *H* moves past the fixed knife *J* and a section is cut, the section sliding off the knife on to the surface of a suitable liquid contained in a dish *K*. It is of importance to note that the cutting motion is initiated by gravity and the elasticity of the spring, two forces which may be assumed to act repeatedly in a reproducible manner. To prevent the arm *E* from carrying out free oscillations, damping is introduced by means of a piston moving in an oil cylinder *D*. By adjusting the magnitude of this damping, the speed at which the specimen passes the knife in cutting can also be controlled.

Fig. 3. Section of aluminium. (× 24,000)

The excitation current for the solenoid and that for the heating and magnetostriction coil are both derived from a d.c. source, which is periodically switched on and off by two small commutators. The required intermittent action is thus obtained, and, since the two commutators are mounted on the same spindle, which is driven by a small motor, the necessary synchronization between the two currents is ensured ; the permanent magnet *F* is raised each time after the nickel core has been magnetized and the specimen retracted ; the magnet is released, and the section cut, after the core has been demagnetized.

The Thickness of Sections

The energy dissipated in the heating coil (and thus the speed at which the nickel core expands) is independent of the speed of rotation of the commutators. However, the number of sections made per second is proportional to this speed of rotation, and, by altering the speed of the motor, the thickness of the sections can be varied quite simply. Another method is to alter the current in the heating coil. This also causes a change in the magnitude of the magnetrostriction, but in practice this is always so much larger than the thickness of a section (Fig. 1) that there is never any danger of the specimen touching the knife on its return journey.

It is naturally important to be able to estimate the thickness of the sections. This is very difficult during the actual cutting. The following method was therefore introduced:— The knife was first observed through a

(*Concluded on page* 37)

Investigations into the Accuracy of Ball-Bearing Components

By A. KOHAUT. (From *Werkstattstechnik und Maschinenbau*, Vol. 45, No. 10, October 1955, pp. 510-513, 14 illustrations.)

PRECISION ball bearings are frequently incorporated in devices where not only true running but also minimum noise generation is important. Bearings of this type are therefore classified on a noise basis by the makers, who have their own criteria and test equipment. It was considered of interest, however, to make detailed investigations of such bearings. For this purpose, four sets of five bearings, from four different manufacturers, were purchased through ordinary commercial channels, to avoid having bearings which might have been specially selected at the makers' works. The purpose of the investigations was to determine the types of defects occurring in such bearings and their influence on smooth running.

Compared with the large numbers of rolling bearings considered in noise investigations, twenty bearings admittedly represent a very small amount of material for testing. Consequently, this report is mainly confined to giving a detailed study of various defects, indicating those which should be avoided because of their effects on noise generation.

After short running tests for an initial classification according to noise level, the bearings were dismantled, their races examined for precision of manufacture, and the balls investigated for roundness, dimensional differences in sets belonging to the same bearing, and precision of manufacture.

GRADING AND DEFECTS OF BALLS

A ball bearing is basically a vibration generator, since the excitation forces in a bearing are always greater than the damping forces. A complete bearing arrangement can be designed so that it will no longer be a source of vibration excitation, but this is not normally the case. Regardless of the arrangement used, however, it is easily seen that vibration excitation will be greater if there are considerable differences in the diameter of the balls in a particular bearing than if they were of very nearly uniform diameter. The size variation of balls situated next to each other in a bearing is a matter of chance, within the tolerances imposed.

Grading to a specified accuracy serves its purpose only if the magnitude of the tolerance limits is greater than the out-of-roundness variations of the individual balls. If the maximum diameters of a ball show considerable variations, a selection based on small tolerances alone may be of little value. On the whole, it may be said that grading nowadays is fairly satisfactory. In this connection, however, of the 20 ball bearings tested, the grading of 7 of these was very good, and there would appear to be no reason why, with very little extra effort, the remaining 13 should not have been equally satisfactory.

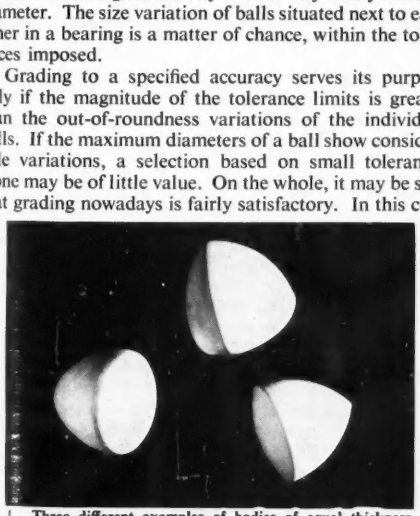

Fig. 1. **Three different examples of bodies of equal thickness, yet not truly spherical.**

Knowledge of noise generation in ball bearings is still incomplete, and opinions diverge on some aspects of this subject, though it is known that even a single defective ball in a bearing has a considerable influence on smooth running. It was therefore decided to make a very accurate surface investigation of all the balls in the bearings considered, using an interference microscope for this purpose (×128). Where further confirmation was necessary, an optical microscope was also employed.

For these tests, a ball-rolling device was set up on the table of the interference microscope, by means of which it was possible to rotate the balls about two mutually perpendicular diameters. If the rate of rotation about one diameter is made considerably slower than that of the other, then the great circles along which observations are taken can follow so close to each other that the entire surface of the ball is effectively investigated. The procedure is long and tedious but it has the advantage of revealing practically all defects in the balls.

These defects can be classified into three groups, i.e., primary defects in ball shape, secondary defects due to assembly, and defects due to corrosion.

PRIMARY DEFECTS

This group comprises what may be called the classical defects of bearing balls, i.e., (a) two-point diameter differences or out-of-roundness errors, (b) non-spherical shapes of constant thickness, and (c) flat spots.

With regard to defects of type (a), it may be noted that the greatest difference in diameters for a single ball was 0·5 micron and this value was measured only once in all the 160 balls investigated.

In the case of defect (b), if the diameters of a " spherical " ball are measured between two parallel planes and the same value is always found, this does not prove that the body is truly spherical, as various bodies with a crowned bottom surface and a domed upper portion, with a constant thickness, can exist (Fig. 1). Balls used in bearings are sometimes of such shapes, but are not a frequent occurrence. Only two of the 160 balls investigated were of this type, and their effect on running smoothness is uncertain.

Defect (c) arises at positions where the curvature of the surface is appreciably less than the normal spherical curvature. This defect appears to be far more difficult to avoid than (b), and it is found fairly frequently in all balls. Fig. 2 shows how a flat is identified under the interference microscope by the peculiar shape of the interference lines.

Minor deviations from the spherical shape appear as irregularities in the circular contour of one or more rings. It can be assumed that these errors do not affect the running smoothness. Flat spots, however, definitely have an adverse effect. A number of the 6-mm balls investigated had flat spots of up to 0·5 mm or even greater. As flat spots are fairly frequent, there does not seem to be so far a method of selection which indicates this defect with certainty.

Secondary Defects

This group comprises the various defects occurring in the assembly of balls into their bearings. Such defects should not occur at all, in principle, but unfortunately they are not as rare as might be assumed and are found in bearings of all makes. In Fig. 3, the interference lines clearly indicate an impression caused by a fairly sharp edge on the ball after manufacture, i.e., during bearing assembly. In many ball bearings, the last ball can be inserted only when the outer race is somewhat (elastically) deformed. If the ball is forced into the bearing, groove-shaped indentations may occur, as illustrated in Fig. 3. For precision ball bearings, this method of ball insertion is therefore questionable.

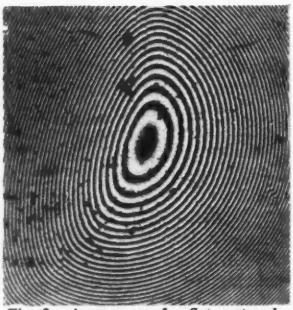

Fig. 2. Appearance of a flat spot under the interference microscope.

Fig. 3. Groove-shaped indentation in the surface of a 6-mm steel ball.

Fig. 4. Surface defects suggesting that the ball has been forced over a sharp edge.

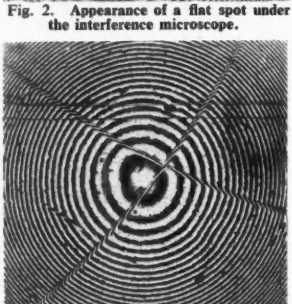

Fig. 5. Tiny scratches on the surface of a ball.

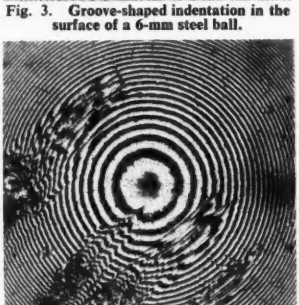

Fig. 6. Portion of an incipient "corrosion line" on a 6-mm ball.

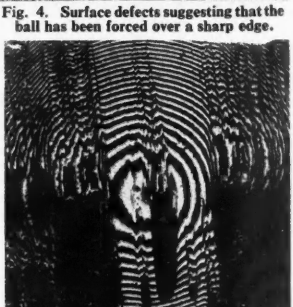

Fig. 7. Portion of a "corrosion line" more advanced than that shown in Fig. 6.

Occasionally, secondary defects of a comparatively minor nature, such as those shown in Fig. 4, and tiny scratches (Fig. 5), hardly affecting smooth running, can be observed ; however, the influence of indentations such as that shown in Fig. 3 is considerable.

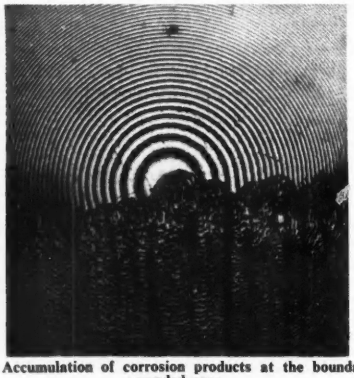

Fig. 8. Accumulation of corrosion products at the boundary of a corroded area.

Corrosion Defects

The defects in this group are avoidable and those associated with ordinary rust phenomena are not discussed in this report. However, the investigations revealed in a remarkable number of cases a characteristic corrosion which was hitherto unknown to the author. This corrosion appears in the form of lines or bands and is presumably of an electrolytic nature. When the damage is not too far advanced, the "corrosion lines" appear as shown in Figs. 6 and 7. Where the interference lines are deflected inwards, i.e., towards the apex of the spheroid, damaged areas have been formed within the ball surface. With further progress of corrosion, the ball surface becomes more densely covered with corrosion lines, and finally these lines cover the surface without any discontinuity (Fig. 8). If these lines are followed in the direction of their width, it is found that the boundary on one side is a clean depression, whereas the other boundary shows an accumulation of corrosion products. Such accumulations are particularly visible in Fig. 8.

If the damage is due to electrolytic corrosion, it should be particularly noticeable at the points of contact of the balls and the races, and hence also on the races themselves. Moreover, as the points of contact between balls and races occur on great-circle lines, the corrosion lines should also be situated on great circles on the balls. Both inferences were confirmed in the investigations.

The corrosion lines on the races are similar in all respects to those found on the balls, with a bright boundary on one side and dull areas, with heavily marked corrosion, towards the other. Complete details of the

dull corroded areas cannot be obtained by the interference method, but it is easy to measure the depth of corrosion roughness by means of a film replica. In most cases the depth is between 1 and 3 microns.

Electrolytic corrosion can occur only if an electrolyte is present. It is difficult to understand its source and how it can maintain itself in cleaned and preserved bearings. The investigations do not provide a definite answer to this problem but suggest the following:—Most probably, the electrolyte necessary for corrosion is formed during the cleaning process. For preservation the bearings are then immersed in hot vaseline, but this apparently does not eliminate all the detergent residues. Therefore, it is important to clean the bearings by processes which do not allow any electrolyte to be initially formed in them. The fact that such a possibility exists was proved indirectly in the investigations. Electrolytic corrosion of the type described was not found in any of the bearings of one particular manufacturer, and it was subsequently ascertained that the cleaning procedure used in their works differs substantially from those employed by other makers, whereas the preservation process is the same.

The extent to which this electrolytic type of corrosion may effect running smoothness will depend on how far advanced it is when a bearing is put into operation. As its development depends on conditions which are not clearly definable, attempts should be made to avoid this corrosion altogether ; for this purpose it is evidently sufficient to employ a suitable cleaning process.

SWEDEN

The Effects of Stresses on Hydrogen Diffusion in Steel

By F. DE KAZINCZY. (From *Jernkontorets Annaler*, Vol. 139, No. 11, 1955, pp. 885–892, 3 illustrations.)

HYDROGEN occupies interstitial positions in the lattice. It therefore seems reasonable to suppose that its diffusion should occur in a manner very similar to that of carbon and nitrogen, but with a smaller heat and entropy of activation. Some abnormal effects, however, have been reported, the nature of which is not clearly understood. Hughes[1] observed as early as 1880 that hydrogen is evolved from a steel sample during mechanical working. It has later been repeatedly observed that, if a hydrogen-charged wire is bent under water or oil, a flush of hydrogen bubbles appears at the surface. Bridgman[2] reported that a hollow steel cylinder containing hydrogen under pressure allowed the hydrogen to escape with explosive violence when the pressure reached 9000 atm. At this pressure a considerable plastic deformation must have occurred. There are also some direct observations which indicate a more complicated diffusion mechanism. Zapffe[3] covered the surface of a hydrogen-charged sample with an oil film and observed the evolution of gas under a microscope. Bubbles of discrete and regular size appeared at deformation markings, such as slip planes or Neumann bands. Recently, Norén and Erikson[4] studied evolution of hydrogen from weld strings on cleavage surfaces with the fractographic method described by Zapffe. During the first 4·5 hours hydrogen was evolved at random sites, indicating lattice diffusion. Sudden formation of bubbles along certain markings, however, was visible for a long time after diffusion through the lattice had practically ceased. It has been assumed that these markings are sub-structural boundaries.

Bhat and Lloyd[5] studied the effect of plastic deformation on hydrogen flow through a steel membrane. The tubes investigated were cold-drawn and not subjected to external stresses during measurement. A 20% reduction had only a slight effect, giving a decrease of about 4% in mild steel. At larger reductions the flow decreased considerably. A similar study was carried out by Schumann and Erdmann-Jesnitzer,[6] who investigated the effect of stretching and cold-rolling. They reported an increase of flow at small, and a decrease at larger, deformations. An accelerated hydrogen evolution has been observed by Shimoda, Onodera, and Yamagata[7] during compression or tension within the elastic range.

In several of these previous studies it is difficult to separate the effects of structural changes caused by plastic deformation, and by external or internal stresses. The evolution of hydrogen, enclosed in molecular state in cavities of sufficient size, involves an additional source of uncertainty. A separate study of only one of these variables, e.g., the effect of stresses on the diffusion rate, might therefore contribute to a better understanding of the problem.

METHOD OF INVESTIGATION

In the present investigation, measurements were made of steady-state hydrogen flow through cylindrical steel tubes subjected to tensile stresses. Hydrogen was discharged electrolytically at the external surface of the

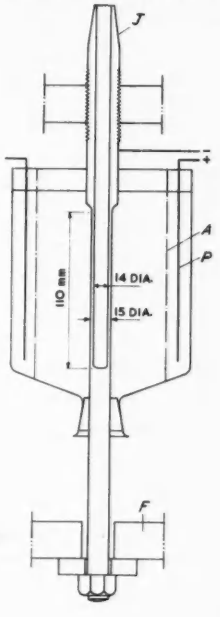

Fig. 1. Assembly of sample for testing.

tube, and the gas evolved at the internal surface was collected in an evacuated bulb. The flow was calculated from the increase of pressure in the bulb.

The composition of the tubes was 0·13 C, 0·23 Si, 0·46 Mn, 0·006 P, and 0·038 S. Five identical tubes were investigated, all in the spheroidized state. The elastic limit of the samples was on an average 19·5 kg/mm², while the 0·2% proof stress was 22·2 kg/mm². External and internal surfaces were ground with emery paper. The shape and dimensions of the tubes are shown in Fig. 1.

The electrolyte consisted of pure normal H_2SO_4. Platinum anodes *P* were used, which were separated from the sample by an alumina diaphragm *A*. The electrolyte was stirred, and its temperature held between 18° and 20° C. Four different current densities were investigated. The resulting equilibrium hydrogen pressure at the external surface, calculated according to the author[8], had values between 2100 and 11,000 atm. All experiments at stresses higher than 20 kg/mm², however, were carried out at the lowest current density (1·9 mA/cm²), in order to prevent early damage to the sample by hydrogen embrittlement.

The upper end of the vertical sample tube was fixed in position, and a frame *F* was suspended from its lower end. During stressing the frame was loaded by means of a hydraulic press. The force was measured with a spring between the frame and the press.

The tube was connected by means of a ground joint *J* to a vacuum apparatus, in which the pressure of evolved hydrogen was measured with a MacLeod gauge. Pressure readings were taken during steady flow every five minutes. The experiments started with determination of the flow in the unloaded state, usually 16 hours after electrolytic charging was initiated. Then, the sample was loaded and the flow measured at constant stress. Finally, a check measurement was carried out after unloading. A statistical treatment of the values obtained from pressure readings during one hour or more permitted determination of the flow with an error of less than 1%.

Results

After loading, which resulted in little or no plastic deformation, steady-state flow was obtained within a few minutes. The flow after stress release was in most cases equal to that before loading. In a few cases, however, a slight increase or decrease was obtained. These variations did not show any regular behaviour, and it is reasonable to assume that they were due to slight variations in the activity of discharged hydrogen. A sample not subjected to stresses showed the same type of variations. In such experiments the flow in the unstressed state was estimated by interpolating the values obtained before and after stressing.

The increase in hydrogen flow was almost proportional to the tensile stress. At the highest stress in this range (24·6 kg/mm²), the flow increased 6·1%. The results are shown in Fig. 2, in which the ratio of flow between the stressed and unstressed state is plotted on a logarithmic scale ($\log(q/q_0)$) against stress. The value of current density had no measurable effect.

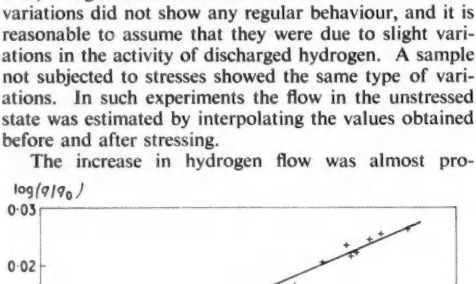

Fig. 2. **Increase in hydrogen flow in annealed steel.**

When the stress was raised to 25 kg/mm² or more (corresponding to at least 0·6% plastic elongation) the flow increased appreciably above the value expected from the relationship in Fig. 2. After stress release the flow returned to the neighbourhood of its original value, although there was a tendency to slight increase. Because of the above-mentioned variations of flow in the unloaded state, the permanent effect of plastic deformation could not be determined with sufficient accuracy. The total permanent increase of flow after the largest deformation can be estimated as 3 to 5%. The time taken to obtain steady flow increased if stressing involved additional plastic deformation. This is due to formation of new cavities in the structure (vacancies), which had to be filled with hydrogen. The highest stress investigated in this way was 33·1 kg/mm², involving a plastic elongation of 5·6%. Two of the samples fractured at 35·2 and 33·5 kg/mm² respectively. Fracture occurred in both cases at the upper end of the thin tube, just below the change in diameter.

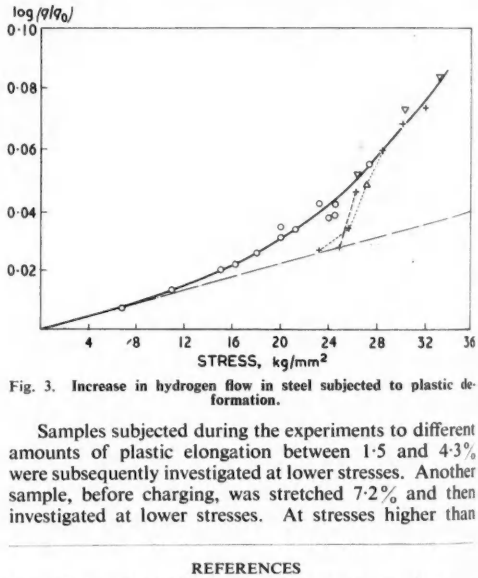

Fig. 3. **Increase in hydrogen flow in steel subjected to plastic deformation.**

Samples subjected during the experiments to different amounts of plastic elongation between 1·5 and 4·3% were subsequently investigated at lower stresses. Another sample, before charging, was stretched 7·2% and then investigated at lower stresses. At stresses higher than

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about 11 kg/mm² all these samples showed an increased effect of stresses on hydrogen flow. The degree of previous plastic deformation within this range did not affect the results appreciably.

The results are plotted in Fig. 3. The values along the curve show the increase in hydrogen flow under tensile stresses in steel subjected to plastic elongation between 1·0 and 7·2%. Open circles represent measurements on samples which had been deformed in previous experiments at higher stresses, while the other markings indicate results obtained at a stress at which the sample was subjected to an additional deformation. The logarithmic flow ratio is not proportional to the stress, as with annealed steel.

These measurements indicate that the passage of hydrogen through sound annealed steel takes place by lattice diffusion in a regular, homogeneous manner.

In the absence of external stresses, plastic deformation had only a slight effect on hydrogen flow in the range investigated. In the stressed state, however, the flow increased considerably more than would be expected in the case of homogeneous lattice diffusion. A possible explanation is that plastic deformation creates certain zones in which the external stress is multipled. They may be comparatively narrow, with a high stress multiplication factor. In these the activity coefficient of hydrogen would be decreased, which, especially in the presence of high external stresses, would result in an inhomogeneous distribution of flow through the sample. Hydrogen would pass more readily through the highly stressed zones. If it is assumed that such zones are located along slip planes of other deformation planes, previous observations could be explained by this hypothesis.

RUSSIA

Automatic Control of Cutting Speed by the Temperature of the Cutting-Tool Edge

By P. N. MALAKHOV. (From *Vestnik Mashinostroyenya*, No. 4, April 1955, pp. 26-30, 4 illustrations.)

In cutting operations, the temperature at the cutting edge is a recognized indicator of cutting conditions, and the maintenance of a prescribed temperature may be the best means of achieving optimum results. Apparatus for the automatic control of this operation is described in this article.

THE temperature arising at the cutting edge of the tool during machining operations is an important factor in determining the work of the cutting tool and the time when it becomes too blunt for efficient cutting. If the shape of the cutting edge, the tool material, the feed rate, and the depth of cut remain constant, then the temperature of the cutting edge, when machining cast iron, is determined by the (simplified) equation

$$T_c = v^{0.36} H^{0.61} C_1 \quad .. \quad .. \quad .. \quad (1)$$

When machining steel, the equation becomes

$$T_s = v^{0.5} \sigma^{0.75} C_2 \quad .. \quad .. \quad .. \quad (2)$$

where T_c and T_s are the temperatures [°C] of the cutting edge, v is the cutting speed [m/min], H is the Brinell hardness of cast iron, σ is the ultimate tensile strength of steel [kg/mm²], and C_1 and C_2 are constants.

The control of cutting speed can be accomplished by a device which varies the speed, in accordance with the hardness (for cast iron) or the tensile strength (for steel). If the machine tool incorporates an automatic electrical control, it is not necessary to evaluate the cutting speed, because the optimum cutting speed can be automatically adjusted to maintain a given temperature.

An electrical control system for this purpose (Fig. 1), developed in Russia, consists of a measuring, an amplifying, and a servomotor unit. In the measuring unit, a coil (1) wound on a frame, a magnet (2) of an electromagnetic millivoltmeter, and two photoelectric cells (3) and (3a) constitute the pick-up unit. These cells, which are illuminated by a small lamp (4), are located inside two dark boxes ; slots (5) and (5a) are separated by a screen (6), the width of which is equal to that of an opening (7) in a semi-annular shutter (8) ; this shutter, which controls the passage of light to the photoelectric cells, is rigidly connected to the coil (1), the winding of which is in series with the thermocouple (9) produced by the cutting tool and the machined component themselves. This thermocouple issues the intitial signal to the control device. The tool is insulated from its support by a fibre plate. Under the action of the thermoelectric current the frame and shutter (8) rotate, the displacement of the frame, and hence of the shutter, depending on the temperature of the thermocouple.

The amplifying unit is made up of two triodes (10) and (10a), which are supplied from transformers (11) and (11a). The input circuits of the triodes contain relays (12) and (13), which respectively control the coils (14) and (15) of the magnetic contactors (24) and (25).

The servomotor unit includes the two contactor coils (14) and (15) and the motor (16), which, by means of the screw (17) and nut (18), displaces the sliding contact of the control rheostat (19) in the circuit of the exciter winding (20) of the main lathe drive motor (21). The control unit is supplied by the auto-transformer (22), with output tappings for 120, 220, and 380 V. A rectifier (23) is included in the circuit.

When light impinges on the photoelectric cell (3), the coil of the relay (12) is energized and completes the circuit through the contactor coil (14), thereby switching on the servomotor (16) through the contacts (24). This causes the sliding contact of the control rheostat (19) to introduce progressively a higher resistance into the exciter winding (20) and thus to increase the rotational speed of the main drive motor. Conversely, when light impinges on the photoelectric cell (3a), a similar chain of events is initiated, the servomotor being switched on through contacts (25), and the rotational speed of the main drive motor is reduced. The contactor coils (14) and (15) are blocked against each other by the normally closed contacts (26) and (27), and also have normally closed contacts (28) and (29) in series with the control circuit of the main drive motor.

The control rheostat (19) is fitted with a limit switch at each end (each with three contacts (30a), (30b), and (30c), or (31a), (31b), and (31c)), which engage the stop

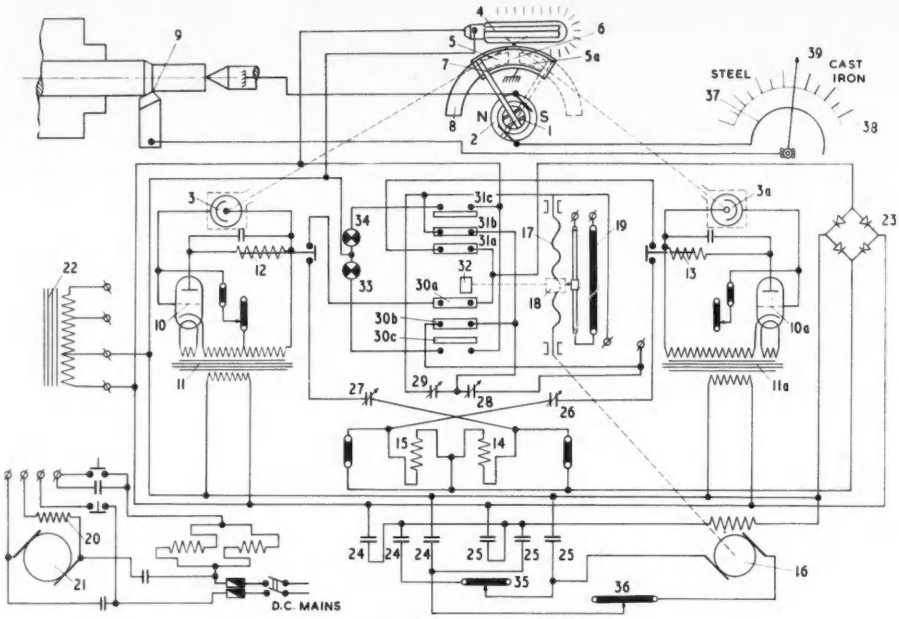

Fig. 1. Circuit diagram of control system.

(32). When the sliding contact of the rheostat takes up a limiting position in which the rheostat is fully in circuit but the temperature of the cutting edge has not yet attained its nominal value, the stop (32) opens contacts (30a) and (30b). At this instant, the circuit in the contactor coil (14) is interrupted, as well as the control circuit of the main drive motor. Both the servomotor and the main drive motor stop, and contact (30c) immediately switches on a blue signal lamp (33), indicating that the machine tool should be set for a higher speed range.

Conversely, when the rheostat (19) reaches the opposite extreme position, in which the rheostat is fully bypassed but the temperature of the cutting edge already exceeds the nominal value, the stop (32) opens contacts (31a) and (31b), thereby interrupting the circuit in the contactor coil (15) and the control of the main drive motor. Once again, the servomotor and the main drive motor stop, but in this case contact (31c) serves to switch on a red signal lamp (34), indicating that the speed range selected is too high.

In this way the operation of the equipment permits cutting to be effected only within the range of rotational speeds corresponding to the optimum temperature of the cutting edge. For stable operation of the control equipment it is necessary that the rate of change of cutting-edge temperature should correspond to that of rotational speed ; otherwise, over-control of the equipment is inevitable. To ensure this condition, the circuit of the automatic control device includes rheostats (35) and (36) in the servomotor armature circuit.

When the control equipment is intended for work with a variety of materials, further elements for adjustment are introduced. A resistance (37) is inserted into the winding of the coil (1) and the front panel carries a scale (38) which shows the correct relative positions of the rheostat (37) and its control knob (39), in accordance with the material being machined and that of the cutting tool.

Before this equipment was tested under shop conditions, a laboratory investigation was carried out. The machined components were made of cast iron or of forged and cast steel from various melts (under these conditions, the chemical composition of the machined components is different, even when the material specification is identical). All components were calibrated, and the maximum differences in temperature within the same material specification for an identical thermocouple e.m.f. were found to be about 7%.

Additional laboratory experiments established that the servocontrol device maintains the set voltage with satisfactory accuracy. It was also possible to verify that the relations between temperature and cutting speed were those given by eqs. (1) and (2). When a high-speed steel tool consists of a tool holder and a brazed tool bit, an additional thermocouple e.m.f. may arise. Experiments were conducted to determine whether, by the use of a cutting coolant, the temperature of the brazed joints could be held low enough to neglect this secondary thermocouple effect. These experiments have shown that suitable coolants can achieve the required results.

After the initial tests with laboratory equipment, an industrial version was designed and constructed. This version was tested under shop conditions. The control equipment was set up on a lathe, powered by a d.c. shunt motor, and used for cutting off railway axles. This machine employs simultaneously four cutting off tools, two at each end of the axle. Of these, one tool at each end performs the roughing work, while the other finishes the end face. The lathe was designed for changing the spindle speed from a maximum of 1540 rpm to a minimum of 700 rpm. The machine was operated for five months and gave an average increase in productivity of 25%. This could have been further increased if the control range of the main drive motor had been increased from 2 : 1 to 4 : 1.

Basic Design Considerations for Electrical Temperature Control

By D. T. KING. (From *Machine Design*, Vol. 27, No. 10, October 1955, pp. 189-200, 11 illustrations.)

The design of any temperature-controlled system requires more than the mere selection of a heater and a thermostat and their installation in a suitable location. This article discusses some of the major factors affecting the design of temperature-controlled systems and the more common types of controllers.

IN any discussion of the accuracy of temperature control, three terms will frequently be encountered, i.e., (1) controller resolution sensitivity ; (2) controller operating differential ; and (3) process system band-width (Fig. 1).

Controller resolution sensitivity can be defined as the minimum temperature band required to cycle the electrical contacts of the controller. It is the inherent sensitivity of the controller itself, a measure of the minimum temperature change to which it can respond under the most favourable conditions. This can be thought of as a theoretical rather than a practical consideration.

Controller operating differential is the difference in temperature (measured at the outer surface of the temperature-sensitive element) required to cause the contacts of the controller to open and close when the device is in control of a particular process. The distinction is that the operating differential refers to the actual performance of the device in a given temperature-controlled process. The operating differential of a controller will almost always be greater than its inherent sensitivity.

Process system band-width is the difference between the maximum and minimum temperatures measured at a point in the thermal system which can be considered the useful working area. System band-width is an end measure of the practical temperature control effected in a given application. System band-width is not merely a function of the operating differential of the thermostat. It is very dependent upon such characteristics of the system as thermal inertia of the heated components, relative location of heaters and controller, variations in heat requirements, heat balance, and frequency of operation of the control element. The mean temperature is a numerical average between the maximum and the minimum band-width temperatures.

SELECTION OF CONTROLLERS

A wide variety of temperature controllers is available, ranging from tiny, compact units, particularly desirable where space is at a premium and weight must be considered, to elaborate electronic types which can be located at great distances from the system to be controlled.

In applications where the operator never needs to change the set temperature of the thermostat, or where he can conveniently make an occasional adjustment, if required, one of the less expensive types should usually be selected. If the portion of the controller which responds to changes in temperature must be in an inaccessible location, and the operator must make occasional changes in temperature setting, one of the remotely adjustable types should be chosen.

If a remote type is required, then it should be established whether the operator must also be able to observe the actual temperature of the process at the point where adjustments are made. Remotely adjustable types which also indicate the actual temperature are generally more expensive than the simpler remote unit which contains only a calibrated scale. In general, wherever some other means has already been provided for producing a visible indication of the true temperature of the system, choosing an indicating type of controller will result in unnecessary duplication and added expense.

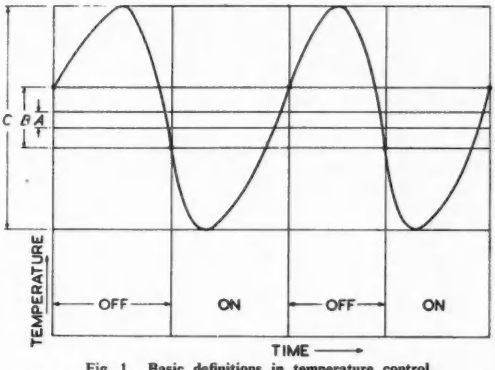

Fig. 1. Basic definitions in temperature control. (*A*) Controller resolution sensitivity. (*B*) Controller operating differential. (*C*) Process system band-width.

Miniature thermostats typify the modern trend toward miniaturization, which has been largely stimulated by, but not confined to, the requirements for airborne equipment. Electric current which can be carried by the various types of thermostat and temperature controllers varies considerably. In general, smaller units are not directly capable of carrying as much current as larger units. Typical values would be 1 or 2 A for miniature sizes, 10 A for a cartridge size, and up to 15 A for the snap-acting type of local thermostat. Units such as the remotely adjustable non-indicating type will operate satisfactorily up to 35 A. Current limitations of smaller types should not restrict their use, however, in applications where they might otherwise be desirable. A relay can usually be incorporated, so that the thermostat controls only the relay coil. Before selecting one of the many temperature-control elements, the designer should give careful consideration to the nature of the system controlled.

SELECTION OF THE HEAT-EXCHANGE MEDIUM

Ideally, the portion of a system housing the temperature controller, the heat source, and the thermal load should be fabricated from materials with high heat conductivity, low density, and low specific heat. Components which are near the thermal system, but which are used primarily for mechanical support or to complete the package as a unit, should be made of materials which are good thermal insulators, commensurate with mechanical strength requirements.

Good conductivity in the temperature-controlled portion of the system is important to minimize temperature gradients and system inertia, or the time required for the heat wave to travel through the material. Too often overlooked, however, are the concepts of light weight and low heat capacity. The weight and thermal capacity of the material directly influence the cost of operating the process, since they determine the quantity of heat required to raise the process temperature a given amount.

Thermal diffusivity (thermal conductivity divided by the product of density and specific heat) is a good measure of the comparative advantages of various materials used as heat-exchange media. Diffusivity then is the heat conductivity of a material divided by the heat capacity per unit volume. Not only is this concept important when selecting materials for the heat-exchange medium, but it should also be considered when choosing a primary control element and particularly when choosing some form of well to protect the primary element.

When attempting to evaluate any temperature-controlled system, it must be recognized that, unlike most other measurable quantities, temperature cannot be measured instantaneously. The response speed of a measuring element will be least important for determining steady-state temperatures. However, it is important when recording temperature fluctuations and rather critical when the element is used to control the temperature.

The use of comparatively slow mercury-in-glass thermometers or bulb-type temperature indicators to evaluate control characteristics of the more sensitive types of primary element used with many temperature controllers can often be very misleading. This is particularly true in rapidly changing systems where the phase relationship between the temperature sensed by the controlling element and that sensed by the indicating element can be displaced by as much as 180 angular degrees, making it appear that the control element is adding heat to the process after it has warmed up and cutting off heat from the process after it has cooled down.

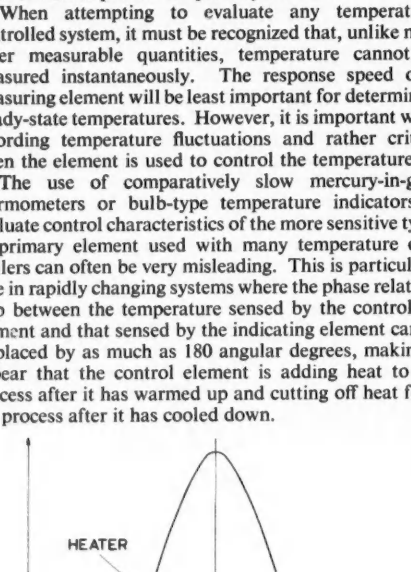

Fig. 2. Temperature gradients in a simple system.

Temperature gradients which might be present in a relatively simple system during a given thermal cycle are illustrated in Fig. 2. The three curves are representative of temperatures which could be measured at the heater, at the thermostat, and in that portion of the system which can be considered the useful working area, *B* being the controller operating differential. This set of curves demonstrates clearly that observation of temperature variations at a given point in the system does not provide a true picture of what is happening throughout the system. Temperature will always be highest near the heat source and will decrease at points progressively farther from the heater. Because of this fact, unless the temperature-controlling element is located very close to the useful working area, it may be necessary to adjust it to operate at a somewhat different temperature, since it does not sense the same absolute temperature as that measured in the working area.

Even if a material with excellent thermal-diffusivity characteristics, such as silver, is used for the heat-exchange medium, a definite period of time will be required for a temperature change occurring in one part of the system to be transmitted to other parts. This thermal lag results in what is frequently termed "temperature overshoot".

There are many practical methods of reducing the effect of system inertia if it is objectionable. A control element with a high response speed can minimize the effect. Using a material with relatively high thermal diffusivity, decreasing the distance between the heater and the control element, or installing a small auxiliary heater near the control element may be desirable.

Probably the most important consideration, however, is the realistic degree of temperature control required in the particular application. It is actually possible to obtain temperature control within very narrow limits. However, in many applications, temperature control within such limits is not really required. Extremely close temperature control should be considered only secondary in importance, since it places an unnecessary cost burden on the apparatus, unless absolutely required.

Actually, the initial cost of the temperature control is not always indicative of the precision obtained. Many relatively inexpensive thermostats can exhibit a sensitivity as good as or better than some elaborate electronic controllers. This is particularly true in units which do not provide snap-action control. By virtue of the fact that contact action is "slow-make", an inherent resolution sensitivity of the order of 0·1° F can be obtained.

Whenever extremely narrow differential temperature control is necessary, and the choice of heat-exchange medium is not fixed because of other factors, it is well to consider the relative advantages of different systems. As a general rule of thumb, which does not take into account individual differences in the properties of materials falling within a given class, the order of preference for close temperature control is as follows : (1) Well-agitated liquids ; (2) rapidly moving air ; (3) high-diffusivity metals ; (4) low-diffusivity solids ; (5) stagnant air ; and (6) stagnant liquids.

Well-circulated fluids can be used to provide closer temperature control than solids, provided that forced convection of the fluid is sufficient to overcome the inherent disadvantages in fluids of poor conductivity and the slow rate of heat transfer resulting from normal convection.

In addition to the fundamental requirements of the heat-exchange medium itself, it is equally important to insulate the heat-transfer material from other sections of the equipment used primarily for mechanical support. In designing a simple barrier between the temperature-controlled sections of the process and those which are used only for mechanical support, the concept of thermal

conductivity is more important in the support sections than that of thermal diffusivity. A laminated structure consisting of two 1-in. metallic plates separated by a very thin sheet of mica can exhibit 100 times the thermal resistance of a 2-in. metal plate. Actually, however, even better than a laminated structure is a thermal barrier consisting of a dead-air space.

Location of Components

Even with identical heaters, temperature controller, and thermal load, widely different magnitudes of temperature control can result merely from the relative location of the various components within a system. The basic location of the various components should be governed by the nature of the application, i.e., whether it is static or dynamic. A static system is one in which the heat demand is practically constant, while a dynamic system is one in which heat requirements vary appreciably.

To summarize the effects which can be obtained by varying the position of the heater and thermostat with respect to the load, it may be said that, with a static system in which heat requirements are comparatively constant, closest temperature control can be obtained by placing the thermostat as near as possible to the heater, with the load at some greater distance. The ability of the thermostat to respond rapidly to temperature changes around the heat source will introduce a series of rapid pulses of heat into the system, approximating in effect a constant heat input. As long as the heat loss of the system remains constant, temperature fluctuations at the load will be kept to a small value.

In a dynamic system, placing the thermostat near the heater is not generally the best solution. With this orientation, although the thermostat can respond quickly to temperature changes at the heater, it cannot, owing to its great distance from the load, respond quickly to changes in heat demand at the useful working area.

Generally, in most practical systems, the most satisfactory arrangement is to compromise somewhat between the two extremes, so that the control element is in a position where it can respond quickly to temperature changes either at the load or at the heater. The closest temperature control will be obtained if the thermostat can be sandwiched between the heater and the useful working area.

In a large system, where the effect of thermal lag may be particularly pronounced, it is often possible to obtain a good averaging effect by using a pair of normally closed thermostats wired in series with the heater circuit. One thermostat can be installed adjacent to the heater, acting as a high-temperature cut-off to prevent excessive temperature overshoot in the area of the heater. The second thermostat, installed near the load, can respond quickly to variations in temperature in that area. Determining the correct temperature setting for each thermostat will probably be an empirical process depending upon heat-gradient characterics and the rate of heat loss from the system, frequency of changes in thermal load, and other factors peculiar to the individual system. Generally, the thermostat near the useful working area would be set at approximately the desired control temperature. The thermostat located near the heater would be set sufficiently higher to provide enough heat under conditions of maximum demand and yet prevent the heater temperature from approaching a level which could cause excessive overshoot in temperature near the load.

Although, for simplification, this discussion has dealt with systems having a single source of heat, the same principles apply when the heat source is made up of a large number of scattered small heaters. Temperature gradients will exist, although they will be of smaller magnitude. Locating the thermal element adjacent to any one heater will increase the cycling rate. An ideal solution is to distribute the heating elements throughout the useful working area and to locate the thermostat in such a position that it can sense representative temperatures of both the heaters and the section to be controlled.

Effect of Heat Balance and Heater Capacity

Heat balance, a measure of heater capacity with respect to the heat requirements of a given system, will have a direct effect on the temperature control attained. In an evenly balanced system, the heater will be energized 50% of the total time. As a general rule of thumb, if the heater is on more than 60% of the time under normal operating conditions, its rating should be increased ; if less than 40%, its rating should be decreased.

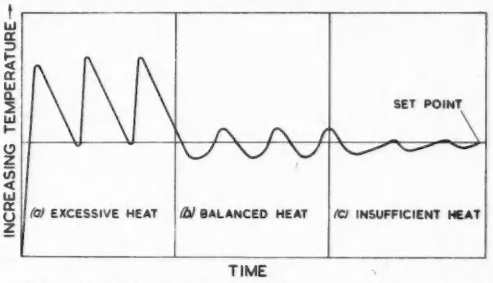

Fig. 3. Effects of heat on temperature fluctuations in a thermal system, resulting from (*a*) too large a heater, (*b*) a heater of the correct capacity, and (*c*) too small a heater.

The set of three temperature-control curves in Fig. 3 demonstrates the importance of correct heat balance in a thermal system. The curve at the left illustrates unsatisfactory control resulting when the heater is several times the required size. In this case, the system temperature rises sharply each time the heater is turned on, subjecting the process to repeated thermal overshoots.

The centre curve in Fig. 3 demonstrates the control obtained in an evenly balanced thermal system. The rates of heating and cooling are approximately equal, and the total temperature deviations from the centre of the control band are small. This system is sufficiently flexible to maintain good control, even if the heat demand should increase or be diminished by fairly substantial amounts.

The curve at the right illustrates the control obtained when the size of the heater barely exceeds the basic requirements of the system. Here, even though the heater is on almost continuously, the system is rarely at its controlled temperature, and the rate of response to heat demand is extremely slow. If for any reason the heat demand should be increased on this already underrated system, the heater will operate continuously, but the system will never reach the required temperature. This situation, of course, results in complete loss of control.

When heaters are designed into a system, the transfer of heat from the heater to the heat-transfer medium should be as effective as possible. If the transfer medium is metallic, the most efficient heat transfer can usually be obtained by having the heater cast integrally within the block itself. If this procedure is not possible, the heater should be attached securely to the block and be in intimate contact over as large an area as possible. It is

particularly essential that all dead-air spaces between the heater and the block be reduced to a minimum.

Installations incorporating radiant-type heaters can be treated rather differently from those using the more common tubular, cartridge, or strip type of elements. Since heat transfer is predominantly by radiation, rather than by conduction as with the solid types, it is often possible to minimize the overall thermal mass of the system, thereby substantially reducing process thermal lag. With radiant-type heaters, it is very important to make certain that the radiant energy is directed towards the working area by suitable reflectors and that the heaters themselves are placed to ensure uniform heat distribution.

Regardless of the type of heater selected, it is usually desirable to incorporate the largest practical number of heaters to make up the total desired heat input. The principal advantage of multiple heaters is better, more uniform heat distribution throughout the process, with consequent reduction of extreme thermal gradients among the various portions of the system. The thermal gradient can be further reduced by concentrating more heat where heat losses will be greater, such as near the edges of a moulding press, to maintain a more uniform temperature throughout the working area. Another distinct advantage of using several separate heating elements in a process is that, if it should become necessary to make minor modifications in the thermal characteristics of the systems, individual heaters can be replaced with heaters of a different size to compensate for these changes. Using several individual heaters also minimizes replacement cost, should one burn out.

Proportional Action and Anticipation

In many thermal systems, the controlled temperature must never exceed certain finite limits. An example might be a process for controlling a liquid system in which the liquid must be maintained very close to its volatilizing temperature. In such cases, where the initial thermal overshoot caused by system inertia during the warm-up cycle would be objectionable, controllers with proportional action or anticipation characteristics can be utilized to good advantage.

Thermal inertia will cause some degree of temperature overshoot during the first or warm-up cycle with simple two-position action controllers. Time-modulated proportional control action can be obtained with electronic-type temperature controllers. With these units, a proportional band can be established such that, when the system temperature corresponds to the centre of the selected band, the heater will be energized approximately 50% of the total time. As the control temperature approaches the extremes of the preset band, the heater on-time will approach 100% at the low end and zero per cent at the high end. This can produce a controlled temperature with an extremely narrow thermal differential. With a properly established proportioning band, the characteristic initial overshoot can be eliminated completely.

Anticipation is peculiar to a class of differential-expansion rod-and-tube thermostats. Since the outer shell of the unit changes its length in response to temperature changes, varying degrees of anticipation will result from the use of different materials for the relatively low-expansion internal struts on which the contact assembly is mounted.

At higher rates of temperature change, thermal lag causes the temperature of the internal struts to lag appreciably behind the temperature of the shell. This enables the rapidly expanding or contracting outer shell to actuate the contacts earlier than it would at lower rates.

Anticipating controllers are particularly valuable when used with thermal systems which are often shut down or which, for other reasons, pass through frequent warm-up cycles, since reheat time can be reduced by using a larger than normal heater without objectionable initial temperature overshoot. Location of the thermostat with respect to the heater affects the degree of anticipation obtained with a given unit to a certain extent. The unit will anticipate more if placed near to the heater.

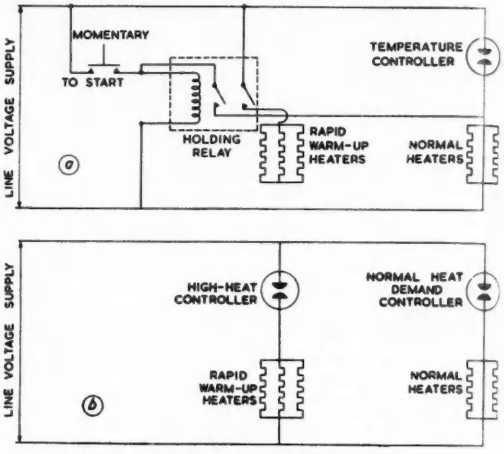

Fig. 4. Two simple methods of obtaining rapid warm-up. (*a*) Manually initiated; (*b*) automatically initiated.

In applications where an especially rapid warm-up is important and the characteristic initial thermal overshoot cannot be tolerated, a thermostat with high anticipation can be utilized very effectively in conjunction with several sets of heaters. The simple relay circuit shown schematically in Fig. 4*a* is only one of many ways of achieving this aim. The relay is actuated initially by an independent warm-up switch or start button and is released when the holding circuit is broken during the first thermostat cycle. Releasing the relay removes the additional heaters from the circuit used to obtain the rapid warm-up. Subsequent control is then effected by the control heaters, which have been sized appropriately to maintain optimum heat balance in the system at the controlled temperature.

The other relatively inexpensive system (Fig. 4*b*) is based on the use of two thermostats. This combination has the advantage of not requiring any manual action to initiate the high-speed warm-up. One thermostat is set to operate a few degrees below the temperature of the control unit and operates the auxiliary set of warm-up heaters. Temperature setting of this thermostat can be established so that the warm-up heaters will not cause an objectionable initial overshoot. Proper temperature setting for the second or auxiliary thermostat, in order to provide the maximum heating rate without objectionable overshoot, can usually best be determined experimentally. This arrangement is quite flexible, particularly because the positioning of components to provide optimum control after the system stabilizes need not be influenced by the need to prevent overshoot during the initial warm-up period. It also has the advantage that the rapid warm-up feature is provided automatically even during a short period of shut-down, or if a new batch of material is added to the process.

Experience with Hydrazine in Reheat Cycles

By R. T. Hess and A. W. Wofford. (From *Power Engineering*, September 1955, pp. 80-84, 7 illustrations.

The application of hydrazine and sodium sulphite, used simultaneously in a single feedwater-steam-condensate system as a possible solution to the problem of oxygen corrosion, is described in this article. During the eight months this treatment has been in use, the results have been encouraging.

The major considerations affecting the decision of the Connecticut Light & Power Company to use hydrazine in the new No. 5 Unit of their Montville plant may be summarized as follows :—

(1) Concern over the possible ineffectiveness of existing chemical treatment, as evidenced by the large amount of metal-oxide sludges often found in present-day high-pressure boilers.

(2) The reluctance to add any solid chemical to the feedwater cycle upstream of the desuperheater water take-off, thereby allowing dissolved solids to by-pass the steam-purifying equipment in the boiler drum and to enter the steam cycle.

(3) The desire to protect the entire system from oxygen corrosion, which is not accomplished when sulphite is added directly to the drum. Under certain conditions, sulphite also has the disadvantage of decomposing to equally harmful products.

Obviously, no single chemical can supply all the answers to these combined problems. Control of the condensate pH by neutralizing amines presents one means of defence. The Company had materially reduced metal pick-up in two 1350-psi units with the use of morpholine ; still, it was felt that pH control was not enough.

Hydrazine, a volatile liquid and a strong reducing agent, offers another possibility. However, information as to its effectiveness was scarce and often contradictory. There was some uncertainty as to whether a residual of hydrazine could be " stored " in the boiler water to handle any sudden air leak. It was hoped that sulphite, used in much smaller quantities than previously, would correct this fault. Evidence shows that the two are compatible.

As a result, the combined theory of feedwater and boiler-water treatment was as follows :—

(1) To condition the boiler water with sodium hydroxide and disodium phosphate to 10·6 to 11·2 pH, 5 to 20 ppm soluble phosphate.

(2) To control the pH of the steam, condensate, and feedwater at 8·9 to 9·1 with morpholine.

(3) To scavenge the residual oxygen in the feedwater system with hydrazine.

(4) To combat any oxygen which might escape the hydrazine by maintaining in the boiler drum the smallest practical residual of sulphite, which should also serve as an indication of sufficient hydrazine in the system.

Fig. 1 is a diagram of the steam and feedwater cycle. It is a closed system with six extraction heaters and a large de-aerating hot well of 16,000-U.S. gal storage capacity. A tangentially-fired steam generator is designed to deliver 625,000 lb/hr of superheated steam at 1500 psi and 1000/1000° F reheat to a 75,000-kW turbine, exhausting into a 55,000-sq ft condenser. Fig. 1 also shows the chemical injection and sampling points, provision being made for the injection of sodium hydroxide, disodium phosphate, sodium sulphite, hydrazine, and morpholine.

A caustic boil-out was the only pre-treatment of the internal boiler surfaces before start-up. In order to proceed cautiously, the water-treatment plan outlined above was applied in phases, as follows :—

Phase No 1, the first three weeks of operation, consisted of boiler-water conditioning only, with sodium hydroxide and disodium phosphate, plus 1 to 5 ppm residual sodium sulphite. The desired chemical concentrations in the boiler water were quickly achieved.

Phase No. 2, the next three weeks, began with the addition of morpholine for pH control. By the end of this period the desired pH had been established with a feed of approximately 11½ millilitres of 100% morpholine per million pounds of steam.

Phase No. 3 was the following two-month period, when hydrazine was used as the only oxygen-scavenging agent, with the elimination of the sulphite. During the first few days of this period, ammonia and conductivity were abnormally high, 0·6 ppm and 6·0 μmhos respec-

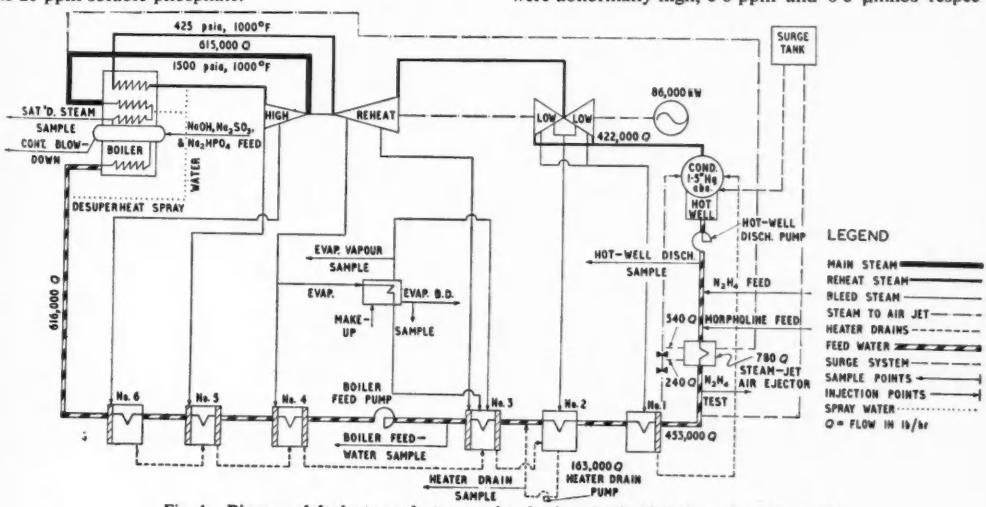

Fig. 1. Diagram of feedwater and steam cycle, showing chemical injection and sampling points.

tively ; however, a more desirable range was soon established with a morpholine feed of 7 ml per million pounds of steam and a hydrazine feed of 0·019 ppm.

Phase No. 4, the final and present operating practice, involves maintaining a small residual of sulphite in the drum, 1 to 2 ppm. This requires less than two ounces of sulphite per day. The hydrazine feed is 0·015 to 0·020 ppm and the morpholine feed is 5 to 6 ml per million pounds of steam.

The hydrazine feed has varied from theoretical (equal in ppm to the oxygen tests at the hot-well pump discharge) to 500% excess, with the most desirable results occurring at 100% excess, i.e., twice the oxygen at the hot-well pump discharge.

At feeds above 50% excess, the oxygen recorders indicated that about half of the oxygen was being removed between the hot-well pump discharge and the boiler feed-pump suction. In contrast, it was found that, with a feed of less than 50% excess, the oxygen at the boiler feed-pump suction gradually increased. The scavenging action of the hydrazine had apparently diminished, for during the same period a sulphite residual was not obtained, although the sulphite charge was more than doubled. Normal scavenging was again accomplished with an increased hydrazine feed. Thus, it appeared that a 100% excess was the optimum dosage rate.

The policy of doubling the oxygen readings at the hot-well pump discharge to determine the hydrazine feed at first gave satisfactory results, but observations showed that a definite minimum feed had to be established. It was found that the reduction of hydrazine feed to below 0·014 ppm is followed by an increase in the oxygen at the hot-well pump discharge. The same effect had occurred several months earlier, but was not recognized at the time.

Evidence led to the suspicion that hydrazine must be present in the hot well before its injection at the hot-well pump discharge. Analytical tests have shown this to be correct. It is a result of recirculating a portion of the hydrazine feed to the hot well by the condensate surge system and the hot-well level control. It is suspected that some also re-cycles with the steam, for traces are found in the heater drains.

Normal concentration of hydrazine in the hot well is approximately 0·01 ppm. Thus, as the condensate is de-aerated mechanically in the condenser, it is further de-aerated chemically in the hot well. Owing to its large capacity, condensate is retained in the hot well approximately 15 min, allowing considerable time for reaction. At reduced loads, the retention time is proportionally increased, and the oxygen readings at the hot-well pump discharge are at their lowest.

The chemical de-aeration in the hot well is more dependent upon the concentration of hydrazine built up in the system than on the immediate feeding rate. Where it had been assumed that the oxygen at the hot-well pump discharge was the only variable in computing the charge required, it now appears that it, too, can be considered constant—in this case, 0·008 ppm (the expected and observed performance of the condenser). On this basis, the charge of 54·4% hydrazine for this base-loaded unit is 200 ml per day.

The delayed-action effect on the oxygen, observed when changing the feed rate, supports the conclusion that the reaction of hydrazine depends upon the presence of ferric iron oxide. The ferric oxide film in the feed system is reduced by the hydrazine to the ferrous oxide, which in turn reacts with the residual oxygen in its tendency to go to its highest oxidized state. These reactions may be visualized thus :—

$$(1)\ldots\ N_2H_4 + 2\,Fe_2O_3 \longrightarrow 4\,FeO + N_2 + 2\,H_2O$$
$$(2)\ldots\ 4\,FeO + O_2 \longrightarrow 2\,Fe_2O_3$$

When the hydrazine feed is decreased to below the amount required to reduce the constant amount of iron surface in the system (regardless of the oxygen present), as in reaction (1), reaction (2) diminishes. However, the latter reaction continues long after the cessation of the hydrazine feed, since there is considerable iron surface in a unit of this size.

The calculated charge of 200 ml per day is the amount necessary to maintain the " hydrazine equilibrium " in the system by replacing that which is used up in reaction and/or decomposition.

In one series of experiments before the build-up of hydrazine in the system, the oxygen recorder at the boiler feed-pump suction indicated normal scavenging many hours after a Haller electrode showed the complete absence of hydrazine. In case of an unusual occurrence, such as an air leak or chemical-pump failure, the system is protected until the routine tests reveal the situation.

Consequently, some of the major objections and uncertainties concerning the use of hydrazine have been investigated and placed in their proper perspective, as follows :—

(1) Existing equipment was all that was necessary to start the application of hydrazine.

(2) Routine analysis, by paradimethyl-amino-benzaldehyde and the Haller electrode, is unnecessary, since the sulphite residual is a more convenient control.

(3) Excessive ammonia is not added to the system, as it can be removed by the mechanical vacuum pump or by intermittently dumping overboard the after-condenser drains from the steam-jet air ejector.

(4) The time for reaction is much longer than at first contemplated, since hydrazine builds up in the system.

(5) Additional protection is achieved by the "flywheel" effect of the hydrazine-iron oxide-oxygen reactions, plus the second line of defence afforded by the sulphite.

(6) Although hydrazine must be treated with respect, handling precautions are not impractical.

Visible Results

The alkaline nature of both hydrazine and morpholine has contributed to reducing the demand for solid chemicals in the boiler, and has consequently decreased the blow-down.

All chemical requirements have levelled to a constant amount. Whereas the original feeding set-up involved varying daily charges, the chemical demand can now be anticipated, permitting the solutions to be made up less frequently, thus requiring less operator attention.

The boiler internals have been visually inspected twice since start-up, with pleasing results. A water-hosing of the turbine rotor was all that was necessary to remove a loose amorphous deposit, comprising 90% of SiO_2 and 10% of Fe_2O_3, from the last row of blades in the reheat section. The desuperheat sprays have been used more than expected, owing to excessive boiler reheat surface, a condition which has since been corrected.

Conclusions

(1) Hydrazine can be used successfully as an oxygen-scavenging agent.

(2) Simultaneously, a small sulphite residual can be

carried as a safety measure ; however, its major role is that of a convenient indication of sufficient hydrazine.

(3) A point of "equilibrium" can be established throughout the system, wherein the hydrazine concentration becomes more or less constant.

(4) Some chemical de-aeration occurs in the hot well when this condition of equilibrium is maintained.

(5) Optimum hydrazine feed to maintain this equilibrium is approximately 100% excess. However, a definite minimum feed should be set, since the oxygen reading at the hot-well pump discharge may give a false indication of the de-aerating qualities of the condenser.

(6) Hydrazine contributes to the pH in the boiler, resulting in less caustic feed and, therefore, less solids in the boiler water.

(7) Plant personnel versed in the older methods of treatment can quickly adapt themselves to the feeding and testing procedures.

(8) The conductivity, pH, and oxygen recorders are invaluable tools in analysing conditions in the feedwater-steam-condensate system.

(9) No special chemical mixing or pumping equipment was necessary to initiate the use of hydrazine.

(10) The use of hydrazine adapts itself satisfactorily in a new unit design, since the chemical equipment can be smaller and less cumbersome than at present.

(11) The use of such small amounts of sulphite does not add appreciable solids to the boiler or its decomposition products to the steam.

(12) The dual use of hydrazine and sulphite tends to overrule most of the objections raised to the use of either material separately.

(13) By employing proper safety precautions in the handling of hydrazine, no difficulties have been encountered.

It should be noted that the results reported in this paper were achieved on a base-load unit employing a large hot well and closed heaters.

AUSTRIA

Recent Developments in Sonic Dust-Extraction Processes

By R. JAHN. (From *Radex Rundschau*, No. 7, November 1955, pp. 625-631, 9 illustrations.)

THE sonic processing of dust-laden gases has been the subject of detailed investigations but most of the work hitherto carried out has been confined to ultrasonic treatments. Ultrasonic waves can be radiated as concentrated beams of energy in sonic-treatment chambers and the standing waves thus generated produce a longitudinal excitation, and hence a flocculation (i.e., agglomeration in the form of thin flakes or wafers) of the dust particles.

The phenomena of dust agglomeration by means of ultrasound have been described by Palmé, who indicated that flocculation is due to (a) the different amplitudes and phases of the movements of particles under ultrasonic excitation, which are functions of the mass (or size) of the various particles, the collisions between particles being proportional to the square of the dust concentration ; (b) the hydrodynamic attraction forces between particles, as well as wall effects ; and (c) the vibratory pressure of the particles, which is greatest midway between two half-waves.

Other contributory factors are the frequency and intensity of excitation, the type of dust, the exposure time, the temperature and moisture content of the carrier gas, and its kinematic viscosity. The type of dust collector to be chosen depends on the required agglomeration efficiency. With a suitable choice it is possible to obtain practically 100% dust extraction.

On the basis of a large number of tests, it has been proved by the author that dust extraction in the audible sonic region produces considerably increased flocculation. Separation from the carrier gas is facilitated by the larger sizes of agglomerates obtained.

In a 22,000-cps ultrasonic field, the nodal regions where the dust agglomerates are situated 0·87 cm apart. In the case of a sonic-treatment chamber of 1 cubic metre capacity and 1 metre in height, 128 nodal areas are formed per square metre of cross-section, corresponding to a total surface of 128 m² for the nodal areas. The dust is collected and flocculates in these areas. If the volumetric flow through the chamber is, say, 3 m³/sec for a gas with a dust density of 8 gr/m², there will be altogether 24 gr of dust distributed over a surface area of 128 m². Under these conditions, the agglomerates produced can be only of a very small size. However, if with similar quantities and chamber dimensions the sonic energy is generated at, say, 1500 cps, then the distance between the nodes will be 12 cm approximately, with a total of 8 nodal areas and only 8 m² of surface area for the flocculation of the 24 gr of dust. As a result, considerably larger dust agglomerates will be obtained.

Every sonic field dissipates energy (in the form of heat). In an ultrasonic field of 22,000 cps, with a dust density of 8 gr/m³, as much as 50 to 60% of the sonic energy is absorbed over a distance of 30 cm, whereas at a frequency of 1500 cps, only 5 to 6% of the energy is lost through sound absorption. Thus, there are economical advantages to be derived from treating with audible sonic frequencies instead of with ultrasound.

Fig. 1 is a photomicrograph of dust distribution in an untreated gas. Examples of the aggregates obtained after

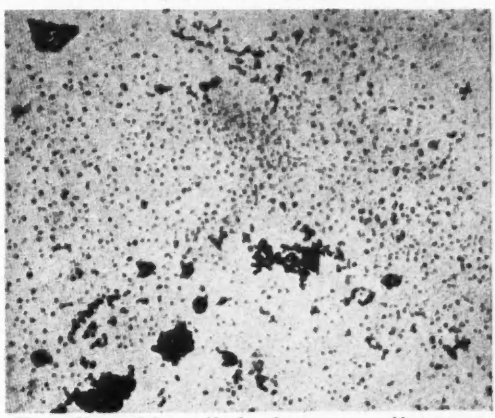

Fig. 1. Untreated iron oxide dust from an oxygen-blast process. (× 500)

sonic treatment at frequencies between 1500 and 3000 cps are shown in Figs. 2 and 3. The author has carried out a series of large-scale tests with widely different dusts, i.e., from ferro-silicon and carbide furnaces, from iron oxide, (produced in the oxygen-blast process in converters), from cobalt oxide, and from ash from the steam-boiler combustion chambers. In all cases the equipment employed had basically similar components. From the gas stream, the untreated gas was aspirated by means of a fan and led into a sonic-treatment chamber of rectangular or square section, which was protected against leakage of sonic energy by sound-reflecting screens at its inlet and outlet orifices. In one instance the agglomerates were then led to a plate-type separator, whereas in other plants various large and small cyclones were used for separation. In one test-plant a bag-type filter was added after the cyclone. The tests were carried out with gas flow rates of 3000 to 5000 m^3/hr (nominal) and at temperatures between 50 and 300° C.

Maximum aggregation is attained only with standing waves. These, however, are produced at low frequencies (1000 to 3000 cps) only if every possible leakage of sonic energy is prevented. Leakage may occur through any fairly large orifice in the walls, and the effect of this flow of sonic energy is then to superimpose travelling waves on the standing-wave pattern in the chamber. The nodes of pressure and velocity are then no longer true maximum positions, as required for efficient agglomeration. It is, of course, necessary to provide orifices for the ingress and exit of the gases, but these openings can be made impervious to sonic energy, while allowing a steady gas flow to take place, if they are provided with a perforated plate with orifices which are smaller than one half-wavelength of the sound. Various designs of sound-reflecting screens were tried out and gave excellent results.

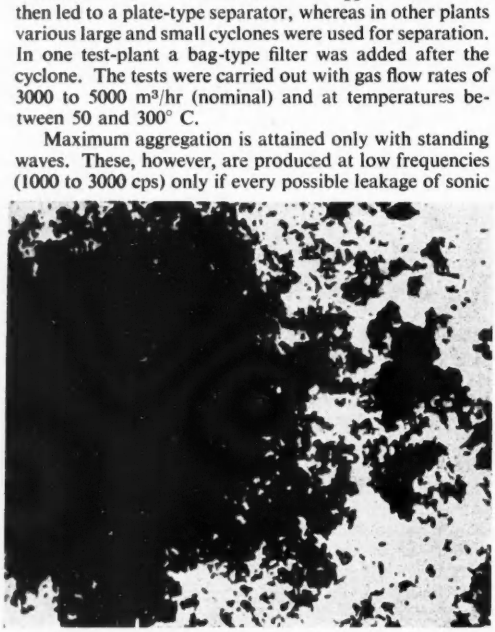

Fig. 2. Large agglomerates of iron oxide, partly scattered owing to impingement on the test slide. (× 100)
Sonic exposure time: 0·5 sec. Sound intensity: 0·1 W/cm^2.

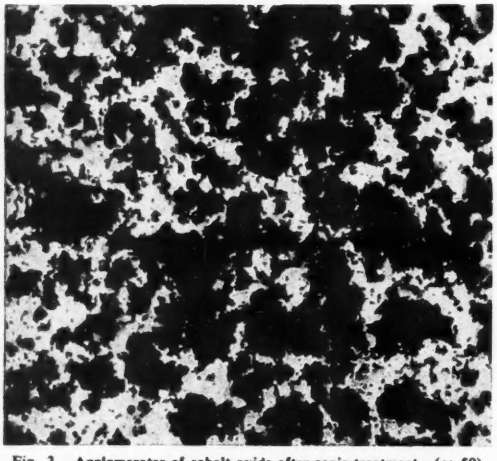

Fig. 3. Agglomerates of cobalt oxide after sonic treatment. (× 50)
Sonic exposure time: 1 sec. Sound intensity: 0·1 W/cm^2.

As the smallest particles of dust vibrate with the greatest amplitudes, these particles are the first to agglomerate ; in other words, agglomeration begins with the finest dust particles of sizes up to 10 microns. The agglomeration progresses during the time provided for sonic treatment, until only large agglomerates are present. According to experience, to obtain a good agglomeration efficiency, the sound generator should produce a field with a sonic intensity not greater than 0·2 W/cm^2 ; however, this intensity also depends on the dust density, the type of dust, and the properties of the carrier gas. The dust density should always be as high as possible, since dust concentrations below 0·8 gr/cm^3 can be collected successfully only under certain conditions. Fractional agglomeration usually gives the desired results.

The moisture content of the gases is an important factor for agglomeration below 100° C. The dew point is the critical value. Vapour condensing in the sonic-treatment chamber increases particle adhesion, but it has a great disadvantage in that the moist particles are not at all suitable for separation by means of cyclones, where they would soon cover the walls with thick layers, rendering the cyclone completely ineffective. Only plate-type separators may then be used.

In all the untreated gases, 85 to 90% of the dust particles had a free-fall velocity of up to 0·6 cm/sec. Owing to the sonic treatment, large-size agglomerates were produced with a free-fall velocity of 44 to 80 cm/sec, corresponding to a ten-fold increase in size (i.e., up to 100 microns), for specific gravities of 3·0 to 3·5. The real diameter of these flakes, however, was sometimes 1000 microns or more. All these agglomerates form flakes or wafers which do not have a very high adhesion strength. Increased exposure time and the use of a sonic intensity five times greater than normal were tried, but gave no further improvement in the adhesion strength of the particles. The agglomerates dispersed again when the air stream reached a certain value. It was found that an air flow of about 10 to 15 m/sec is sufficient to produce complete dispersal of the agglomerated particles. The critical value of velocity depends on the cohesion obtained. Agglomerates suspended in a flow of gas then break up when impinging tangentially upon a wall. Tests with a cyclone showed that a gas flow velocity of 10 m/sec at the cyclone inlet resulted in a fully successful separation of agglomerates, whereas with an increase to 14 m/sec all the agglomerates disintegrated on the walls of the cyclone and were again carried away as fine dust by the gas stream. Accordingly, it may be noted that with a modern cyclone a good separation is obtained only under certain conditions. The velocity criterion of cyclone efficacy and the critical velocity of dispersion of the agglomerates are unfortunately situated very close to one another, so that a cyclone, or any type of separation in a vortex sink, is suitable only for certain conditions.

Where the quantities of gas are fairly small, an effort should be made to obtain the largest possible sizes of agglomerated particles, in order that these may be separated by precipitation. For large quantities of gas, the most suitable separators are those which do not break up the agglomerates and which use a spiral-type flow pattern for separation. By irradiating these separators with sonic energy and ensuring that only standing waves are present, it is also possible to obtain an accumulation of non-adhering dusts by means of the sound waves at the nodal regions or nodal points, and then collect these fine-dust accumulations by centrifugal force. Tests in this direction were very successful.

The sound-reflecting screen surfaces arranged in the treatment chamber are impervious to sound but their resistance to the gas flow is at most between 5 and 8 mm water-gauge. The sonic energy then remains in the treatment chamber, which should be constructed with very rigid walls to avoid resonance as far as possible.

The noise produced outside the installation is not greater than normal factory noise ; in two cases where noise measurements were taken it amounted to only 75 phons at 3 metres from the equipment. By means of sound-absorbing materials arranged outside the treatment chamber, it should be possible to reduce the noise level to between 50 and 60 phons.

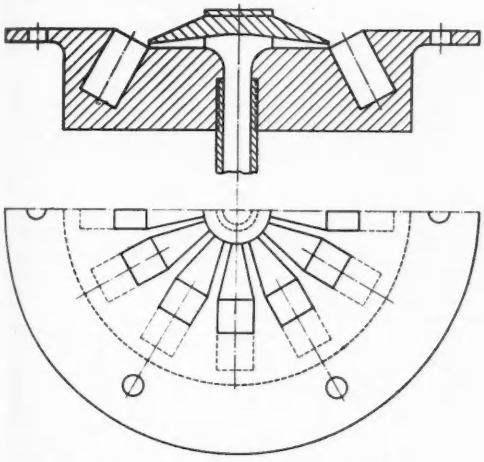

Fig. 4. Sonic generator with quarter-wave pipes.

As regards sonic generators, three different systems can be employed, i.e., pipe types of various designs, electro-acoustic reed types, and toothed-rotor types of sirens actuated by a jet of air or some other suitable fluid medium. For easily agglomerated dusts, pipe-type generators were found quite adequate. A schematic drawing of a sound generator of this type is shown in Fig. 4. This arrangement consists of 12 pipes situated around a circle and operated by an air jet at 280 m/sec. The pipe lengths are determined so as to obtain the required frequencies (quarter-wave types of pipes). There are no rotating parts and these generators give good results.

Electro-acoustic transducers have not been used for ultrasonic dust collection and are also unsuitable for audible-sound systems for dust extraction. For high sonic intensities, siren-type generators are most suitable, in view of their simple construction ; frequencies of 1000 to 3000 cps can be produced at speeds of 6000 rpm. In one construction, the air jet is supplied continuously to a rotor which is provided with deflector blades. These feed the jet to alternate sets of pipes, which are provided with horns for improved radiation characteristics. The siren radiates sound on both sides, with phases in opposition. This phase difference is compensated by means of sound-conducting pipes of different lengths and all the radiation into the sonic-treatment chamber is of the same phase. By means of this arrangement the efficiency of the sirens is raised to about 75%.

Sirens can be operated with cold or high-temperature gases ; in the latter case, the sirens are made from ceramics. It is important, particularly with hot furnace gases having a high dust content, to be able to operate the siren with hot gases, because dusts which become pasty at high temperatures or which are suspended in the gas flow in a molten state can then be agglomerated into wafers of larger size, so that precipitation is obtained in the sonic-treatment chamber in most cases, with a substantial reduction in losses.

It is of interest to compare the results obtained with the various basically different types of equipment so far developed for dust collection, i.e., dry cyclones, bag-type filters, electrical systems, and sonic dust extraction. Cyclones are the simplest and cheapest means of dust collection, requiring only a small amount of space and reaching overall dust-collection efficiencies of 95 to 98%. However, their " fine-particle " efficiency, for fine particles with a free-fall velocity of up to 0·5 cm/sec is only between 8 and 20%. These fine dust particles are frequently the most dangerous and their removal is most important (for instance, in air preheaters). Fly-ash analyses of a coal-dust combustion plant have shown that about 95% of the particles are of diameters below 2 microns (with free-fall velocities of about 0·02 cm/sec), although they constitute only 5% of the total weight of the fly-ash. Thus, it is not possible to separate fine dust by means of cyclones. The pressure loss in cyclones is 10 to 70 mm water gauge, depending on the type of dust and the extraction efficiency. The power required for extraction, with a pressure loss of 50 mm, is about 185 W per 1000 m^3 of untreated gas, assuming a gas flow of the order of 225,000 m^3 per hour. To treat this same quantity per hour with a bag-type filter, about 240 W/m^3 would be required. The fine-particle efficiency for grain sizes of up to 5 microns amounts to 50%, so that, here again, the fine dusts cannot be retained with this filter.

A large-size electrical dust-collecting plant for 225,000 m^3 of gas per hour requires electrical energy of about 220 W per 1000 m^3 of gas. The power consumption rises, however, when fine dusts, up to 5 microns in diameter, have to be separated. The pressure losses amount to approximately 5 mm water gauge. This type of plant obviously requires a considerable space, since it must operate at low gas flow velocities.

For sonic dust-extraction equipment, on the basis of the test results so far available, a maximum energy consumption of 220 W per 1000 m^3 per hour can be estimated. The measured pressure losses are 5 mm water gauge, as in the case of the electrical equipment. Hence, the energy required is similar in both cases. However, the sonic dust-extraction process separates all the fine dust particles, since these are the first to be agglomerated ; furthermore, it occupies much less space and is less costly. The sonic process of dust extraction should therefore be considered wherever large quantities of gas are to be processed, with complete removal of fine particles, provided that the dust can be agglomerated.

HOLLAND

Stresses in Pressure Vessels

By W. P. KERKHOF. (From *De Ingenieur*, Vol. 67, No. 45, November 11, 1955, pp. W.131-W.138, and No. 46, November 18, 1955, pp. W.141-W.148, 16 illustrations.)

In this paper an attempt has been made to calculate allowable stresses, inclusive of local stress-raisers, on a sound basis in accordance with present knowledge. At the same time, the necessity for introducing a weld efficiency factor is discussed. Endeavours are made to avoid the safety factors now in use, replacing them by other, smaller factors which can be calculated or estimated with reasonable accuracy. In addition, several possibilities of failure are discussed and, because of the lack of knowledge, the safest value is chosen as a criterion for determining allowable stresses.

IN order to avoid misunderstanding, the definitions of terms used in this article are as follows :—

The *total real stresses* are the stresses occurring in a part of the vessel, and are the sum of internal stresses and stresses due to load, taking into account the result of yielding, strain-hardening, etc. The load can be any combination of internal pressure, bolt load, loads due to temperature differences, local loads, etc.

The expression *real stresses* is used for the stresses due to load only. These real stresses should be identical with the calculated stresses. It is obvious that a rupture theory can be used only if the calculated stresses are in fact about the same as the real stresses.

The maximum stress which the part under consideration can safely withstand is the *allowable stress*. The real stress or the calculated stress must never exceed the allowable stress. Generally, the calculated stress is a combination of a membrane stress, which is uniformly distributed over the plate thickness, and a non-uniform stress, which is very often of the bending type. Bending stresses without membrane stresses often occur ; membrane stresses without bending stresses occur only at certain points in the shell.

Regarding the internal stresses, a distinction has been made between original residual stresses which occurred before loading the vessel, and ultimate residual stresses which remained after loading followed by unloading.

If the expression " stress " is used, attention is drawn to the magnitude of the stress as such and not to the stress variations occurring. The total stress is the sum of the stress due to load and residual stress.

The *stress range* is the difference between the stress due to load and the stress in the unloaded condition. The stress range therefore refers to stress variations. Residual stresses can never be included.

The *design stress* is a theoretical tabulated stress to be used for the calculation. The allowable stress can be calculated by multiplying the design stress by the stress-concentration factor.

In many cases the stresses calculated with the theory of elasticity happen to be above the yield point. Such a high stress cannot usually occur. This stress will therefore be called the *theoretical elastic stress*.

It will be shown that all allowable stress ranges are above the yield point of the steel. This involves use of the plastic theory. Furthermore, it is understood that the value of the yield point should be known for the purpose of such a calculation. It is a recognized fact that, for similar steels, the yield point varies considerably. Accordingly, the real yield point should not be used, but in its stead, a minimum value should be applied, found statistically as a result of many tests, and tabulated in such a way that the steel manufacturer can guarantee these data. Such tabulated yield-point values are used in several countries.

It is obvious that the minimum yield-point curve should represent a safe minimum. In this case a safety factor relative to the yield point, to cover variations in mechanical properties, is not required.

It is impossible to apply the same method of calculation to every conceivable case. The following limitations should therefore be mentioned :—

(a) The method of calculation is to be used only for stable structures, such as cylindrical shells, domed ends, flat ends, etc. In cases in which elastic or plastic instability occurs, the calculation will not be used. This means that it is not suitable for shells under external pressure or for any details which have a tendency to lateral buckling, such as stiffeners, gusset stays, girders, etc.

(b) It is assumed that the temperature is above the transition temperature of the material, so that brittle rupture at low temperatures cannot occur.

(c) The temperature must not be so high that creep becomes an important feature. The maximum temperature for which the calculation may be used is, in the case of carbon steel, about 400° C.

(d) It is assumed that no shock-loading occurs.

(e) The number of full stress cycles, due to loading and unloading, is not to exceed, say, 25,000, coinciding with two full stress cycles per day throughout about 35 years. This means that high strain fatigue has to be taken into account.

(f) It is assumed that boiler steel of good quality is used, so that local yielding may occur without greatly influencing the mechanical properties of the steel. The theory, however, is applicable to all the usual steels, irrespective of the ratio of yield point to ultimate tensile strength.

(g) It is presumed that the vessel or boiler is insulated in a conventional manner, and that heating up and cooling down are carried out slowly enough to ensure that no severe temperature stresses can occur.

In order to avoid undue complication, the following simplifications have been introduced :—

(h) The stress-strain curves shown are very simplified.

(j) The Bauschinger effect has been neglected.

(k) If a plate is subjected to a membrane stress and a superimposed bending stress, it is assumed that the elastic straight-line relation of the stress-strain diagram is valid until the plate yields over the whole cross-section.

(l) If the theoretical stress is partly above the yield point, but not so great that yielding over the whole cross-section occurs, a small permanent strain after unloading remains. This permanent strain is neglected.

These simplifications, however, do not affect the principle of the following analysis.

(1) POSSIBILITIES OF FAILURE

A rupture theory has to explain the failures occurring in practice. It is, of course, presumed that no overload occurs in service. Assuming no special corrosive conditions to be present, the following most important possibilities of failure may be observed :—

(a) *A non-permissible plastic deformation during the*

hydrostatic test or during blowing of the safety device. It is obvious that such a plastic deformation can occur only if the high stress is distributed over a large area. Local stresses never produce great plastic deformation.

(b) *Rupture, without appreciable plastic deformation.* Rupture occurs almost exclusively near limited areas of stress concentration, or near defects in the plate material or weld material. Such defects also cause very high stress raisers, so that the limited area of stress concentration mentioned is the only point of origin of rupture.

This rupture has the following characteristics :—

(1) Normally, it does not occur during the hydrostatic test, notwithstanding the fact that the stresses during the test are higher than during service.

(2) A crack occurs only after some service time, often after an appreciably long time.

(3) The crack nearly always extends very slowly.

(4) The material surrounding the crack is always hard and brittle, even in cases in which the material has no appreciable tendency to age-hardening.

(5) The fracture looks brittle. Shear fracture does not occur.

(6) Vessels which are frequently loaded and unloaded are more subject to rupture than vessels which are more constantly under pressure.

(c) Corrosion which causes a uniform decrease in wall thickness is not considered to be a possible source of failure. This corrosion may be avoided by selecting a suitable material or by making the service time long enough by adding a reasonable corrosion allowance. The type of corrosion to be reckoned with is local attack of the material, near welds and near areas of high stress concentration, which may be the cause of the vessel's rejection after a rather short service time. This local corrosion may take the form of a fairly uniform attack, pitting, or corrosion cracking. As local corrosion occurs near areas of high stress concentration, this stress corrosion is often combined with a tendency to rupture, as described under (b).

(2) Plastic Deformation

Prevention of non-permissible plastic deformation does not mean that all calculated elastic stresses should be below the yield point. Great plastic deformation can occur only if the material yields throughout its whole thickness.

The stresses in a shell may be considered as a membrane stress σ_m, acting in the heart of the plate, and a superimposed bending stress σ_b. The total theoretical elastic stress σ_{tot} is then the sum of σ_m and σ_b. Neglecting strain-hardening, yielding over the whole thickness of the plate occurs if

$$\sigma_b = \frac{3}{2}\sigma_y - \frac{3\sigma_m{}^2}{2\sigma_y} \quad .. \quad .. \quad (1)$$

where σ_y is the yield point. In the case of pure membrane stresses ($\sigma_b = 0$), total yielding occurs if $\sigma_m = \sigma_y$.

In the case of pure bending stresses ($\sigma_m = 0$) severe yielding occurs if $\sigma_b = \frac{3}{2}\sigma_y$, which is in agreement with the result of many tests carried out by Baker and his collaborators.[1] Notwithstanding the simplifications introduced, eq. (1) is in accordance with test results.

Pure bending occurs in flat ends of pressure vessels. Pure membrane stresses occur only very locally, owing to the fact that the cylindrical shell is never truly round. Accordingly, a combination of membrane stresses and bending stresses always has to be reckoned with.

(3) Rupture

Great plastic deformation and strain-hardening at static load can only occur in parts where the high stresses are distributed over a large area, such as the cylindrical shell and the centre of flat end-plates. In other parts of the vessel (e.g., in the knuckle of domed ends, near branches, stays, and in the hub near flanges), the high stresses are very localized in at least two directions. This means that the part that yields is very small and surrounded by fully elastic material, which prevents any excessive local deformation. The strain at the stress raiser is also very small, because it is restricted by the strain of the surrounding elastic material. No strain-hardening therefore occurs during first loading. However, if the local stress raiser is high, strain-hardening occurs after certain stress cycles almost without deformation. This can be proved by applying the theory developed by Orowan.[2] This theory, which is quite in accordance with the characteristics of rupture described in Section (1), is also in agreement with the results of investigations carried out in the U.S.A.[3,4,5] One of the conclusions drawn from these investigations was that, as regards pressure vessels, the ultimate tensile strength may be a better criterion than the yield point. This conclusion, however, is not justified, as will be seen later.

As a result of tests, it was found that the strain ranges causing rupture after 25,000 stress cycles were much greater than the strain ranges causing yielding followed by reverse yielding. It is thus obvious that, for atmospheric temperatures, rupture can never occur if the total stress range

$$\sigma_{tot} \leqq 2\sigma_y \quad .. \quad .. \quad .. \quad (2)$$

In this case, strain-hardening is impossible during the life of the vessel, and the stress does not become appreciably higher than the yield point.

In the case of boilers which are warm in the loaded condition and cold when not loaded, eq. (2) is modified, as follows :—

$$\sigma_{tot} \leqq \sigma_y + \sigma_{yt} \quad .. \quad .. \quad .. \quad (2a)$$

in which σ_y is the yield point at atmospheric temperature and σ_{yt} the yield point at the working temperature t.

For pressure vessels, however, which may be at zero pressure at working temperature, it is obvious that the formula to be used should be

$$\sigma_{tot} \leqq 2\sigma_{yt} \quad .. \quad .. \quad .. \quad (2b)$$

This equation gives the lowest and safest allowable stress and is proposed for application to both boilers and pressure vessels, with a view to uniformity in calculation.

Owing to the limitation of the allowable local stress raiser in accordance with eq. (2b), no rupture and no strain-hardening can occur. To prevent rupture alone, and admitting strain-hardening, an even higher stress range seems to be acceptable. In the following it will be shown that strain-hardening should be prevented, in order to inhibit local corrosion. In this case the strain-hardening as such, and not the rupture, is the criterion to be taken most strictly into account. This means that the yield point, and not the tensile strength, has to be used for the calculation giving the most severe requirement.

(4) Shear Strain Energy Theory

Eqs. (1), (2), (2a), and (2b) are applicable only to a

uni-axial state of stress. In the case of a multi-axial state of stress, such as that occurring in pressure vessels, the shear strain energy theory has to be used. If it is supposed that the true tensile or compressive stresses in three mutually perpendicular directions are σ_1, σ_2, and σ_3, and the three corresponding shearing stresses are τ_{12}, τ_{31}, and τ_{23}, yielding takes place if

$$\sigma_y = \sqrt{\sigma_1^2+\sigma_2^2+\sigma_3^2-\sigma_1\sigma_2-\sigma_3\sigma_1-\sigma_2\sigma_3+3\tau_{12}^2+3\tau_{31}^2+3\tau_{23}} \quad . . \quad (3)$$

This equation will be used for calculation of the equivalent uni-axial stress range.

(5) Internal and Total Stresses, and Stress Range

The maximum values of the initial internal stresess occurring as a result of rolling or welding are of the same order of magnitude as the yield point of the material. The stresses due to welding are very localized in at least two directions. This means that, if yielding occurs as a result of residual stresses and superimposed stresses due to load, no excessive plastic deformation is caused. In this case it is, of course, supposed that the stress due to load, as such, does not cause excessive plastic deformation.

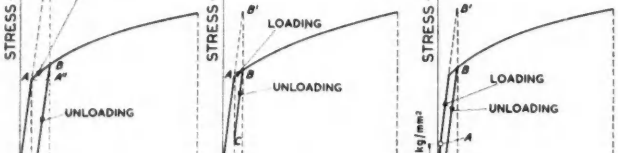

Fig. 1. Influence of residual stresses.

In the stress-strain diagram in Fig. 1a, the initial residual stress is assumed to be $A'A$ (yield point), the corresponding strain being OA'. The theoretical elastic stress $A''B'$, which is presumed to be greater than the yield point, has now to be added to the initial residual stress, so that the total theoretical elastic stress is equal to $B''B'$. If it is assumed that the stress due to load also occurs very locally, the real total stress occurring is equal to $B''B'$. After unloading, the remaining ultimate residual stress is $-A'C$, i.e., about the same as would have been the case if no initial residual stress had been present. The plastic deformation OA' after unloading is about the same as the initial strain due to the initial residual stress. It is obvious that in this case the initial residual stress has no influence at all.

In Fig. 1b it is supposed that the theoretical elastic stress due to load is smaller than the yield point. After the vessel is unloaded, the ultimate residual stress is equal to $A'C$, i.e., approximately the difference between the yield point and the stress due to load. When the vessel is loaded again, the stress does not pass the yield point, so that, in this case, too, no great plastic deformation, strain-hardening, or rupture can occur as a result of initial residual stresses.

Stress-relieved vessels are not entirely without residual stresses. Values as high as about 3·5 kg/mm² have been measured in carbon-steel, thermally heat-treated vessels. It will be shown later that the allowable stresses (not the design stresses) are high, even so high

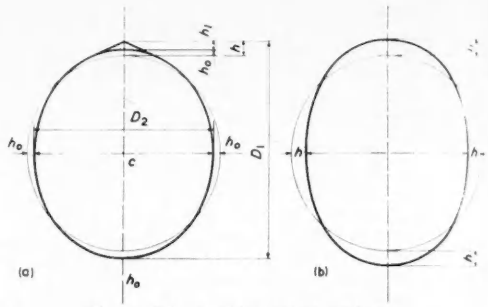

Fig. 2. Influence of local out-of-roundness.

that the sum of the allowable stress and the residual stress after heat treatment (3·5 kg/mm²) is above the yield point. The result of the first loading and unloading of such a vessel at points where the high stresses mentioned occur is shown in Fig. 1c. The ultimate residual stress after unloading $A'C$ is about the same as that shown in Fig. 1a for a non-stress-relieved vessel.

From these considerations, the following important conclusions can be drawn :—

(a) To prevent excessive deformation (see section 2), strain-hardening and rupture (see section 3), only the stress range has to be taken into account. The residual stresses have no influence on strain-hardening, deformation, or rupture.

(b) As regards strain-hardening, excessive deformation, or rupture, there is no difference in behaviour between stress-relieved and non-stress-relieved vessels.

(c) There are always several points where the maximum total stress, i.e., the sum of the stress due to load and the ultimate residual stress, is equal to the yield point.

The latter conclusion leads to enunciation of a very important postulate, as follows :—

" The highest total stresses occurring, i.e., the sum of the stresses due to load and the ultimate residual stresses, exactly follow all variations in yield point which may occur in the vessel."

If the yield point of the weld material is higher than that of the base metal, the highest total stress in the weld is higher than in the base metal. If the plate material has been excessively cold-deformed, resulting in a high yield point (strain-hardening), the highest total stress is higher than is the case when cold-working has been very slight.

(6) Stress Corrosion

Stress-corrosion tests generally give the following results :—

(a) Non-deformed material : No attack.

(b) Only elastically deformed material : No attack.

(c) Only plastically deformed material : No attack or only slight attack.

(d) Elastically and plastically deformed material : severe attack.

It is, of course, presumed that the material used for the tests is reasonably corrosion-resistant.

Instead of " plastically deformed material " the expression " strain-hardened material " may be used, as

plastic deformation without strain-hardening is impossible. On the other hand, strain-hardening due to stress variations without severe plastic deformation is possible.

It is therefore assumed that the cause of stress corrosion is not the plastic deformation as such, but strain-hardening combined with high elastic stresses. This is in agreement with point (d) mentioned above, and also in agreement with the results of pressure-vessel and boiler practice, as very often stress corrosion is found in areas near stress raisers where strain-hardening after a certain number of stress cycles has occurred without severe plastic deformation.

The highest stresses occurring are equal to the yield point, as shown in section 5. The higher the strain-hardening, the higher the yield point and the higher the total stresses. It seems reasonable to assume that, as regards stress corrosion, the total stress, and not the stress range, must be taken into account. Consequently, corrosion is more severe if the strain-hardening is greater. This is, in fact, in agreement with practice.

It should be borne in mind that stress corrosion may cause cracks or other defects on the surface of the metal. Such surface defects, or notches, increase the stress range locally so that, although the original stress range before the notch formed was perhaps not enough to cause rupture, the formed notch, when higher stresses are present, may, nevertheless, subsequently bring about rupture (section 9). In order to prevent such a combination of corrosion and rupture, the mere prevention of corrosion appears to be sufficient, and this may be effected by avoiding any strain-hardening.

In this case the recommended eqs. (1) and (2b), originally developed only with a view to preventing severe strain-hardening, may also be applied to prevent severe local stress corrosion followed by rupture. It is obvious that, for the use of the equations mentioned, only the stress range counts, and not the total stress including residual stress. The latter has no influence on the strain-hardening, as has been shown in section 5.

A further important conclusion is that the allowable stress range is related to the yield point of the material, and not the ultimate tensile strength or fatigue limit, assuming that the fatigue limit for 25,000 stress cycles is above the yield point, which is the case for normal pressure-vessel steels. Only in very exceptional cases, for steels with a relatively very high yield point, has the fatigue strength to be taken into account.

(7) Out-of-Roundness of Cylindrical Shells

Equations to measure the stress due to out-of-roundness have been developed by Marbec[6] and Haigh[7]. Carlson and McKean[8] showed that the stresses thus calculated closely agree with measured values. The maximum radial deviation can easily be measured as a routine inspection.

In nearly all cases the maximum deviation of the nominal radius occurs at the longitudinal weld. The total maximum deviation is considered to be a summation of a deviation due to ovality h_o (Fig. 2a) and a local deviation h_l due to shrinkage of the weld.

First, the diameters D_1 and D_2 should be measured. It follows that

$$D_1 - D_2 = 4h_o + h_l \quad .. \quad .. \quad .. \quad (4)$$

With the aid of a suitable measuring bridge the local deviation h_l can be rather closely approximated, so that the total deviation $h = h_o + h_l$ can be calculated.

The measurement is based on the assumption that c (Fig. 2a) is the centre of gravity of the cross-section. In reality the centre of gravity is higher (assuming the deviation is as indicated in Fig. 2a ; the circle from which the out-of-roundness has to be measured thus also lies slightly higher. The measured deviation is therefore slightly greater than the true deviation.

As the out-of-roundness is very small compared with the radius of the shell, it can be proved by the theory of Marbec[6] that Haigh's formula can be simplified as follows :—

$$\sigma_b = 6\sigma_m \frac{h}{t} \frac{1}{1 + 4\dfrac{(1-\nu^2)}{E}\sigma_m \left(\dfrac{R}{t}\right)^2} \quad .. \quad (5)$$

where σ_b is the maximum bending stress, σ_m the circumferential membrane stress, h the maximum radial displacement, t the shell thickness, ν Poisson's ratio, E Young's modulus, and R the mean radius of the shell. The equation is based on the fact that for small deviations an arbitrary out-of-roundness (h in Fig. 2a) gives the same maximum stress as occurs in a real oval with the same out-of-roundness in Fig. 2b.

As the deviation h measured is slightly greater than the true deviation, the calculation is on the safe side.

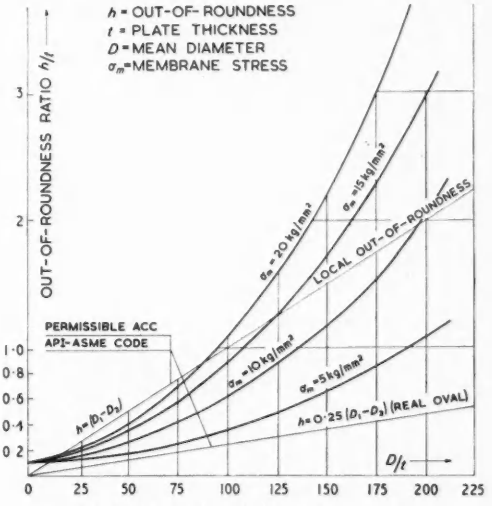

Fig. 3. Curves of permissible out-of-roundness.

Fig. 3 is a graph giving the permissible out-of-roundness ratio $(h/t)/(D/t)$ for various values of σ_m [kg/mm²] assuming that $\sigma_b = \frac{2}{3}\sigma_m$, $E = 2{\cdot}1 \times 10^4$ kg/mm², and $\nu = 0{\cdot}3$.

According to many codes the difference between two diameters at right angles to each other must not exceed 1% of the nominal diameter. If the shell is a true oval, this requirement makes it necessary that $h = 0{\cdot}25\,(D_1 - D_2) = 0{\cdot}0025D$; if the deviation is entirely local (no ovality), $h = D_1 - D_2 = 0{\cdot}01D$. Both lines are shown in Fig. 3. As the usual real value of h is between the two lines mentioned, and the majority of the out-of-roundness lines shown are also between these two limits, the assumption $\sigma_b = \frac{2}{3}\sigma_m$ seems to be very reasonable and can be used for acceptance of the vessel.

The permissible limits shown in Fig. 3 can thus easily be adhered to by the manufacturer. It is therefore proposed to limit the out-of-roundness as shown in Fig. 3.

The maximum stress in the shell is then limited to $1\frac{1}{3}\,\sigma_m$. Such a method of stress limitation is far more logical than the usual requirements given in nearly all codes. Measurement of out-of-roundness as a routine test presents no difficulties, and has been carried out in the Netherlands for many years.

(8) Weld Efficiency

As the highest total stress in a vessel is equal to the yield point of the steel, irrespective of the stress range, it follows that the use of a weld efficiency factor, which reduces the stress range, does not reduce the total stress. Consequently, the use of such a factor is not logical, insofar as total stress and prevention of corrosion are concerned.

This fact is recognized, inasmuch as vessels containing corrosive media have to be heat-treated, regardless of the weld efficiency used. If, however, the influence of corrosion can be ignored, it is not the total stress, but the stress range, which has to be considered. The question as to how the stress range changes if a weld efficiency factor is introduced can be answered by considering the longitudinal weld of the cylindrical shell.

It is known that distortion due to welding increases approximately in proportion to the number of beads, or, in other words, in proportion to the plate thickness. The ratio h/t may therefore be assumed to be constant for each weld efficiency.

Assume a membrane stress $\sigma_m = 10$ kg/mm², $E = 2{\cdot}1 \times 10^4$ kg/mm², and $\nu = 0{\cdot}3$; then, taking the weld efficiency as 1·0, 0·9, 0·8, and 0·7, with R/t ratios of 100, 90, 80, and 70 respectively, the stresses in Table I can be calculated in accordance with eq. 5. In this connection, however, it should be noted that Table I is not used with the Netherlands code, because the weld efficiency factor is used here in calculating permissible out-of-roundness.

Table I: Influence of Weld Efficiency on Total Stress Ranges

Radial deviation h/t	Weld efficiency factor			
	1·0	0·9	0·8	0·7
	Stresses [kg/mm²]			
0·618	12·00	11·44	10·98	10·72
1·236	14·00	13·88	14·00	14·44
1·854	16·00	16·32	16·94	18·16

It seems to be a fairly good approximation to state that the mean value of the total stress range in a cylinder is constant, dependent on the theoretical value of the membrane stress used in the formula, but independent of the weld efficiency factor used.

Furthermore, many pressure vessels work at higher temperatures. The temperature stresses (especially during the heating-up and cooling-down periods), which have to be added to the stress range calculated in Table I are approximately proportional to the plate thickness. Consequently, the stresses in the case of low weld efficiency factors or thick plates are still higher than in the case of thinner plates.

The only conclusion that can be drawn is that the use of a weld efficiency factor decreases neither the total stress, nor the total stress range in the cylindrical shell, and is therefore illogical and uneconomical. There are even reasons to believe that it is safer to use a weld efficiency factor as high as possible, as is shown below.

(9) Defects in the Weld

The theory developed above applies both to stress-relieved and to non-stress-relieved welds without defects. As soon as a weld contains defects, the stresses near the defects are totally different from the values calculated.

Since a defect has an effect similar to that of a notch in a tensile bar, it will be useful to investigate first what the influence of such a notch will be on the strength. In Fig. 4, *A* is a tensile curve of an unnotched test bar. Curve *B* shows the maximum stress in a test bar with a rounded notch. The stress shown represents the maximum tensile stress in the root of the notch ; the strain is assumed to be measured at the same place. The first part of the curve, representing the elastic state, is steeper ; yielding occurs at a higher stress, the ultimate tensile stress is greater, and the strain is less, as compared with the bar without a notch.

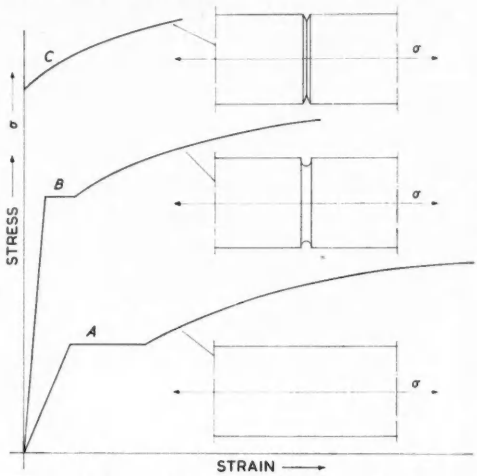

Fig. 4. Influence of notch shape on the stress-strain curve.

Curve *C* is a tensile curve for a bar with a sharp notch. In this case, the curve does not show any elastic stress at all. Even under the slightest load, yielding occurs in the root of the notch at a rather high stress. In the case of a crack, yielding occurs at a stress which is about 2·5 times the yield point—here again, of course, under the slightest load. The stress is thus independent of load and material thickness. If the material cannot yield, the stress in the root of the notch will be much higher than 2·5 times the yield point. In this case, however, the maximum stress is indeed dependent on the load and the plate thickness. These properties of yielding and non-yielding material are very important in further analysis.

(To be continued)

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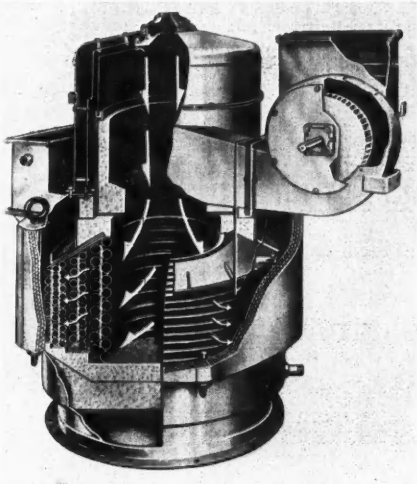
British Industrial Developments

"Vapor" Steam Generator

J. Stone & Co. (Deptford) Ltd. have recently been appointed by the Vapor International Corporation, of Chicago, sole licensees for the construction and marketing in Great Britain and Ireland of the "Vapor" steam generator, with capacities from 500 lb/hr upwards.



Of the many advantages of the "Vapor" steam generator, demonstrated by its success in heating installations for American railways and in ocean-going ships, perhaps the greatest is its economy in fuel, inasmuch as it makes steam only when and as needed, admission of fuel to the burner being automatically regulated to correspond with the demand and as determined by preset controls. The saving in manpower is also considerable. Furthermore, there is no need for an extensive warming-up period before regular working hours, as the required head of steam can be raised in two minutes. Low installation cost is another factor in favour of the unit. No special boiler house, massive foundations, and large chimney stack are required, while the weight is about one-quarter and the size one-fifth of conventional boilers of the same rating. This compactness and comparative lightness permit siting close to the point of actual steam consumption, with a consequent saving in piping and associated line losses.

In principle, the "Vapor" steam generator is a compact, forced-circulation water-tube boiler with several sets of coils nested and connected in series to form a single coil. Feed-water passes through the coil once only. It is not recirculated, and there are no drums, headers, or internal reservoirs. Fuel is admitted to the burner in the proportion required to heat the amount of water passing through the coil at any one moment, thereby generating a controlled steam pressure at the coil outlet. Heat is released in the pressurized combustion chamber at a rate which is from ten to twenty times greater than that obtained with conventional boiler practice. High turbulence forces the hot gases to scrub the coil surfaces and to wipe off any insulating film of relatively cool gas.

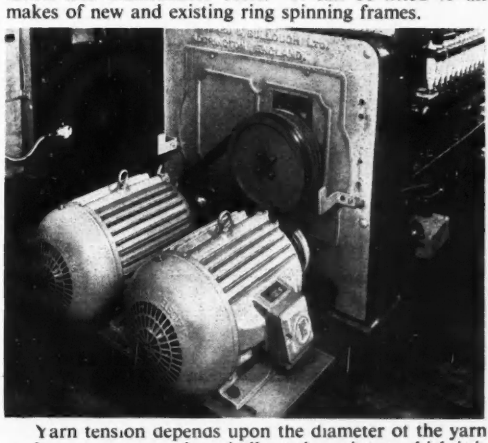
Combustion air is preheated in an air jacket surrounding the upper part of the fire pot and is delivered under forced draught to the burner, where it mixes with the atomized fuel oil. The hot combustion gases are driven down and across the nested coils, which are staggered to ensure maximum contact. The fire is adjusted to evaporate about 90% of the feed-water admitted to the coils. The unevaporated water travels at high speed, carrying scale-forming sludge into a steam separator, where it settles to the sump, and steam of over 99% quality passes through the coil outlet. The thermal efficiency of the generator is from 78 to 82% throughout the whole modulating range.

Protection against breakdown is provided by a servo-control which shuts down the unit completely if the water supply falls below a safe minimum. A temperature-limit control safeguards the coils from the possibility of abnormally high steam temperature due to low water flow. It should be noted, however, that, owing to the relatively small mass of water in the coils, even under full operating conditions there is at no time any danger of explosion. In the event of flame failure water flow is automatically checked either by a pressure switch or a stack switch.

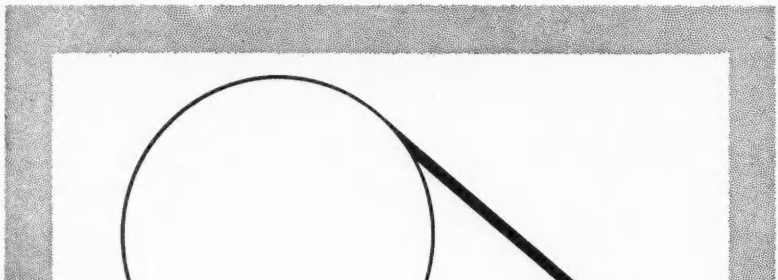
The generator is supplied in a range of seven sizes, covering ratings of 18, 40, 65, 100, 120, 135, and 160 hp. Where steam requirements exceed those of the largest unit, it is usual to install a battery of individual units totalling the required supply. In most cases this will still show a saving in installation costs, as compared with that of installing a conventional boiler of the required capacity. The great advantage of such a battery is, however, the infinite flexibility of its supply. As requirements vary from day to day, or even from hour to hour, one or more units can be cut out or brought into operation in response to varying steam demand, automatically and without supervision.

Drive for Textile Spinning Frames

A simple system for driving textile ring spinning frames, using two identical electric motors, has now been successfully evolved by The English Electric Company, of Stafford. This system, known as the "two-speed drive", ensures an overall low end-breakage rate, with better-quality yarn, higher production, and low installation and maintenance costs. It can be fitted to all makes of new and existing ring spinning frames.



Yarn tension depends upon the diameter of the yarn package, or cop, on the spindle at the point at which it is wound on, and also varies cyclically with the ring rail position. This variable tension creates thin places along the length of the yarn, known as "yarn irregularity". Yarn tension is greatest when being wound on to the

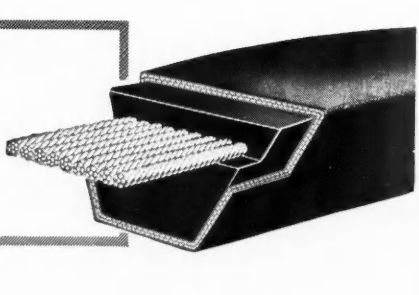


FLEXING?

Flexing in a V-belt presents a challenging problem — how to protect the load carrying cords of a belt from the bending forces within it when passing over a pulley. Goodyear have the answer for *all* V-belts, including those for drives with short centres and small pulleys where flexing is obviously severest. Here, Goodyear overcame this difficulty by placing the cords in the " neutral plane " of the belt, where the bottom compression and top tension forces neutralise. The cords are virtually unaffected by the constant flexing and the belt, consequently, has a longer, trouble-free life.

Whatever your operational problems, the choice of the right Goodyear belt with correct installation and maintenance will give you the maximum efficient service.

F.H.P. BELTS *Designed for single-groove fractional-horsepower drives, Goodyear F.H.P. Belts are built to absorb the shocks of frequent starting and stopping and to withstand the high rates of severe flexing arising from the compactness of short-centre, high-speed, small pulley drives.*



For longer wear | at lower cost

GOODYEAR INDUSTRIAL RUBBER PRODUCTS

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smallest diameter of the conical build of the cop, and is least when approaching the maximum cop diameter. An interesting feature is that the end-breakage rate is greater at the bottom of the package at the commencement of spin, and also at the nose or the end of spin, than it is for the central body of the cop.

The new drive is designed to reduce these end breakages and to increase the production and quality of the yarn itself. Two identical squirrel-cage induction motors, totally enclosed and fan-cooled, are connected together by V-belts and pulleys, one pulley being slightly larger in diameter than the other. A drive is taken from the smaller pulley to the roller shaft of the ring spinning frame. When the motor with the smaller pulley is energized, the frame runs at a lower speed than when the motor with the larger pulley is energized, and thus two driving speeds are available. The actual changes of speed are arranged to take place when the bottom of the cop has been built, and at the nose of the cop, the speed changes being from low to high and then to low. These speed changes are effected by a cam-operated switch attached by a flexible shaft to the ratchet-wheel shaft of the builder motion of the frame. The switch is arranged to operate electrically either of the two main contactors, the contactors being mechanically interlocked so that both cannot be in the "in" position together. For frames fitted with an electromechanical brake to prevent snarls in the yarn when coming to a standstill, a third contactor, which operates before either motor is energized, is provided. Changes of setting for the speed-change switch are very simple and can be accurately made with a screwdriver.

Stud-Welding Technique for Hydraulic Equipment

An interesting example of how increased productivity can be obtained by the introduction of a more economic method has been found in the works of Steel Fabricators Ltd., of Cardiff, who have recently adopted a stud-welding technique, developed by Crompton Parkinson Limited, of London, W.C.2, in preference to arc-welding for the attachment of entry nipples to the curved surface of hydraulic cylinders. Formerly, it was the practice to attach the entry nipples, which serve to attach the feed pipes to the cylinder, by means of manual arc fillet welds. This method was not only time-consuming but difficult, as the heat input was limited by the thin walls of the bosses, and the quality of the weld was impaired by its small circular shape. Moreover, the actual surface of the boss where it abutted the cylinder remained unwelded, thus forming a source of weakness.

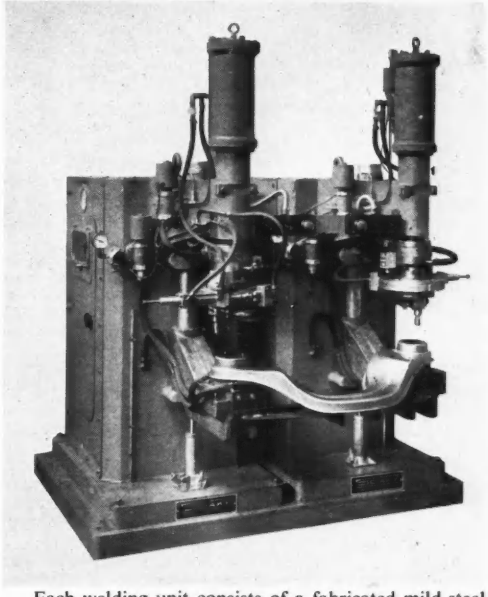
As the cylinders are subjected to pressure tests varying from 1800 to 3000 psi, and to working pressures of 900 psi or more, it is essential that the entry nipples be pressure-tight. In view of the high pressures to be sustained by these connections, stud welding is ideally suitable, in that it provides a strong and solid weld throughout the complete cross-section of a nipple. The entry nipples in this particular case consist of partly drilled $\frac{3}{8}$-in. and $\frac{1}{2}$-in. B.S.P. tapped bosses, and these have to be stud-welded to cylinders of $2\frac{3}{8}$ in. or $3\frac{1}{4}$ in. outer diameter, with a wall thickness of $\frac{5}{32}$ in. The stud welding is carried out with Crompton Parkinson "Cyc-Arc" type E3/D equipment.

To ensure accurate location, the hand-tool is mounted on a drill press by means of two strong clamps and the cylinder placed over a suitably mounted cylindrical jig with a peg inserted as an end stop. A copper insert in the jig ensures suitable support for the weld. After stud welding, the drilling is completed right through the remainder of the boss and the cylinder wall. Pressure tests give fully satisfactory results and approximately 180 of these cylinders can be welded per hour with semi-skilled labour.

A second application on the same cylinder consists in stud welding a plain pin to a bracket, which is then arc-welded to the end of each tube. This pin acts as an end-stop, which prevents the piston from moving beyond the inlet nipple, while the bracket provides the hinge on which the completed cylinder is suspended. Pins of $\frac{5}{8}$ in. diameter are used; these are located on the bracket by means of a special jig and are stud-welded at the rate of six per minute.

Automatic Stitch-Welding Machine

A new stitch-welding machine, type SAm. 75, is announced by Sciaky Electric Welding Machines Limited, of Slough, Bucks. This equipment, which has been designed for the automatic spot welding of two spring cup pressings simultaneously to a cross-member of an automobile suspension unit, consists of two 75-kVA fully automatic stitch-welding machines mounted on a common baseplate at fixed centres.



Each welding unit consists of a fabricated mild-steel frame, to which are fitted arms which permit a working throat depth of 18 in. At the front of each top arm is installed an air-operated pressure-cylinder unit designed for a total ram stroke of 7 in., to enable the component to be loaded and withdrawn from the machine without fouling the electrodes. These long-stroke heads can retract to the normal "up" position, permitting a clearance between the electrodes of 7 in.; in the working position, the heads operate with a $\frac{1}{2}$-in. stroke. To each of these pressure-cylinder assemblies is fitted a "Sciaky" automatic stitch-welding or indexing head. This unit, which can be mounted on any automatic spot-welding machine, consists of a pneumatic-indexing, universal-adjustment design, to produce gas-tight, overlapping spot welds. The electrode fitted to this head can rotate any part of a circle up to a full 360 deg., and the circle is adjustable for any radius up to 3 in.

On each bottom arm is mounted the fixed electrode tooling, designed to accommodate the main pressing, while the height adjustment of both arms can easily be carried out by the operation of built-in hydraulic jacks. The machine is set in operation by a push-button control, and the circuitry is such that the machine can be shut down automatically at the end of the welding run. Weld timing is effected by resistance capacitance units, and the primary current control is by means of a "Sciaky" ignitron contactor unit. The machine is capable of operating at welding speeds of up to 100 welds per minute.

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Hydraulic Test Bay

Believed to be unique in Great Britain, a hydraulic test bay, for the extensive and long-period checking of all hydraulic sub-assemblies of their range of machine tools, has recently been put into operation by The Newall Engineering Company Ltd., of Peterborough.

The test bay, a general view of which is shown in Fig. 1, incorporates a series of units which may either be employed independently for the testing of individual sub-assemblies, or may be coupled for the collective checking of all hydraulically operated assemblies under conditions comparable with their normal function as part of a machine tool. Basically, the test bay consists of a series of frames, on which fixtures are mounted to take a wide variety of sub-assemblies, the fixture being arranged so that the necessary supply lines may be connected rapidly. Weights are incorporated in the system for application to each sub-assembly under test, to create a load in excess of the heaviest likely to be encountered under actual working conditions.

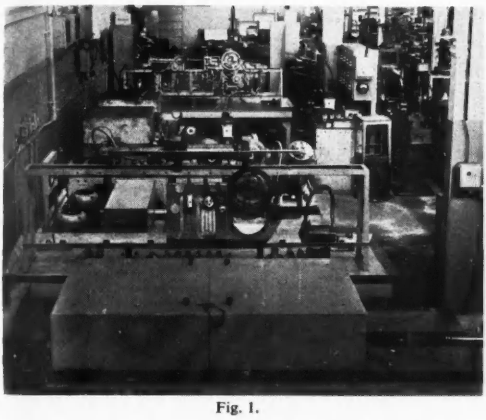

Fig. 1.

The system is operated through an electrical panel by push-buttons activating each unit, while main stop-switches are located at strategic points throughout the test bay, so that operation of any sub-assembly giving evidence of fault may be stopped. Application of the electrical controls brings into play the main hydraulic supply pumps. Two pumps are employed, so that, if only part of the system is in use, one pump may remain inoperative, thereby obviating undue rises in oil temperature and unnecessary continuous circulation of the hydraulic fluid.

Although a number of Newall grinding machines are now being fitted with a unit developed by the company to control oil temperature, this has not been applied to the hydraulic test system, to ensure that assemblies operate under conditions identical with those generally applying in the workshops.

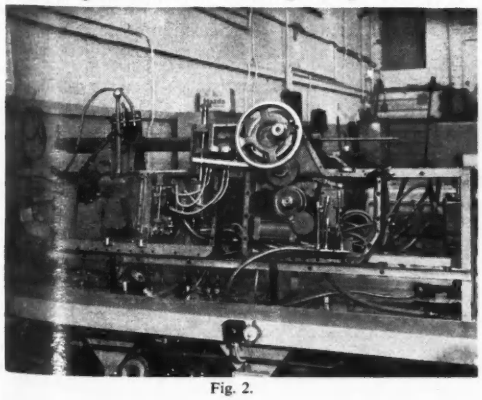

Fig. 2.

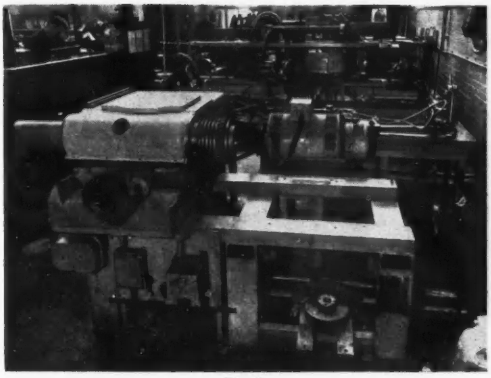

Fig. 3.

Oil for the hydraulic system is pumped from a large-capacity gravity filter and returns to this unit for clarification, so that all exhaust and drainage oil is thoroughly cleansed before re-circulation. The temperature of the oil in the clarifier is recorded on a large dial thermometer mounted near the tank. This panel also includes a dial indicator, registering hydraulic pressure. Additional filtration is provided by small filters in the pressure supply line immediately before each unit.

The system is designed for continuous operation of the individual units, which can run without supervision during the closed hours of the factory. For this purpose the system includes cut-out devices which are brought into operation in case of either excessive pressure developing through blockage or low pressure occurring by reason of leakage or any other fault. To achieve automatic function small control cylinders are attached to levers, normally manually operated.

Designed for the testing of a wide variety of assemblies, such as complete control panels for grinding machines, hydraulic traverse controls of jig borers and wheelhead assemblies, hydraulic pumps, operating cylinders, etc., this test bay has been installed in order to subject all such parts to a testing period equivalent to one month's normal operating in a finished machine.

Fig. 2 shows the complete control panel of a crank-pin grinder undergoing test, while Fig. 3 shows a testing unit for a wheelhead assembly.

Automatic Heat-Treatment Furnace

A new electric furnace has been supplied to and installed in the Witton Works of Imperial Chemical Industries Limited (Metals Division) by G.W.B. Furnaces Limited, of Dudley. This furnace is of the electric-resistance-heated type, and is used for annealing coiled brass strip for the purpose of softening between rolling operations. The installation is of the walking-beam design, in which the coils are lifted for a few inches off the fixed portion of the furnace hearth by means of moving beams, which then move forward and drop once more just below the fixed hearth level, and return to continue the cycle once more. The movement of the beams is arranged to be as nearly rectangular as possible and is effected by two separate motor mechanisms, one for vertical and one for horizontal movement. This method is found to be considerably superior to the eccentric-cam method, which tended to subject the charge to abrasive action when being lifted from and lowered on to the fixed portion of the furnace hearth. This feature becomes quite pronounced in the case of

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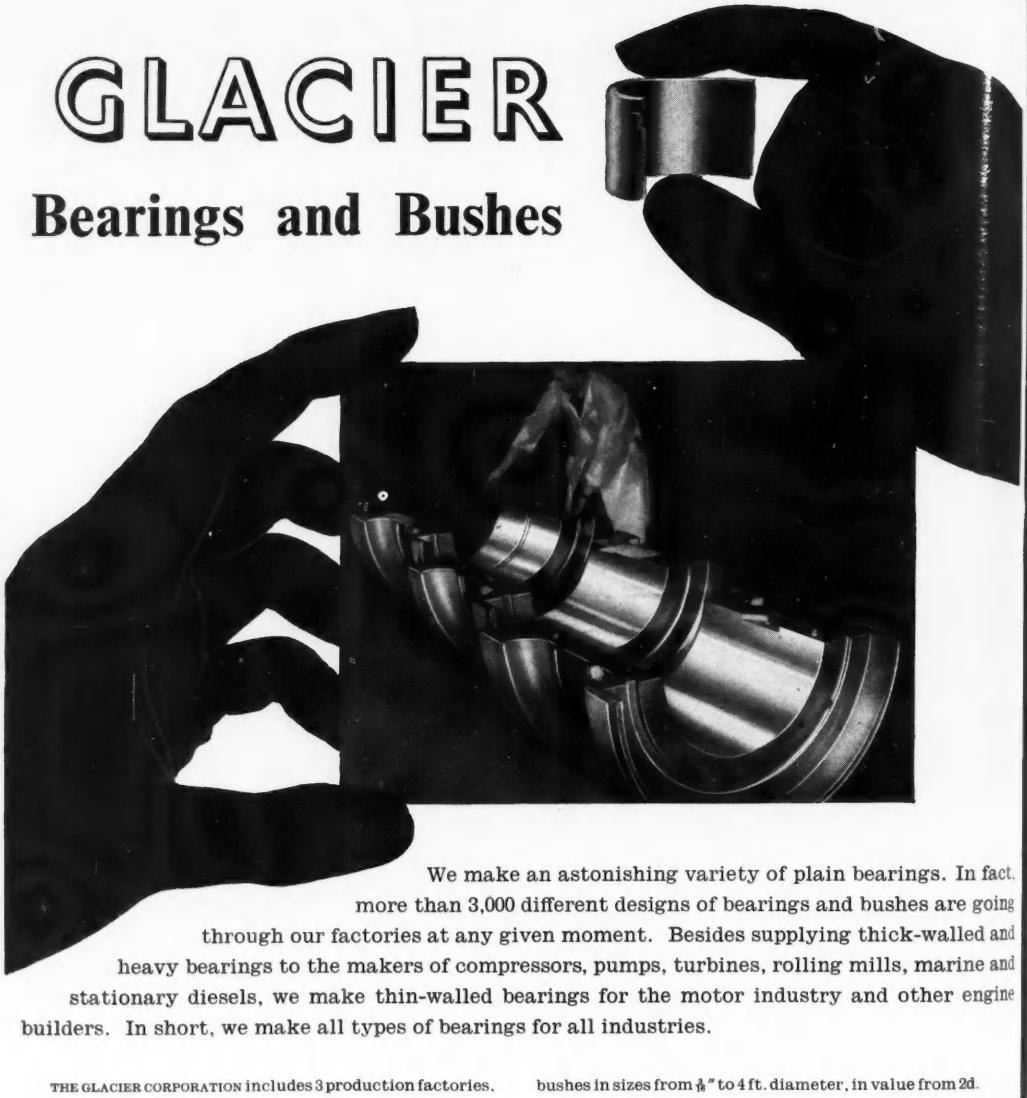
Bearings and Bushes



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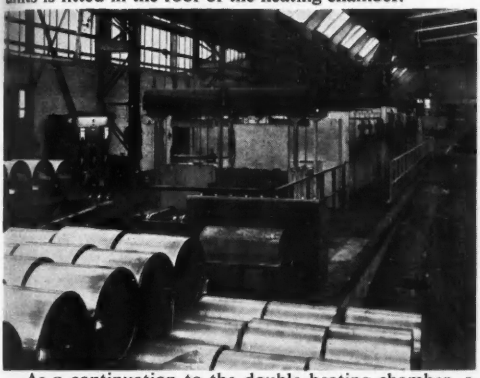
relatively long furnaces such as the new unit, in which the length of moving beam is nearly 50 ft.

The furnace, an overall view of which is shown below, is U-shaped, comprising an ingoing and outgoing beam set side by side, so that the charge and discharge points are adjacent, while change in travel direction of the charge is effected by means of a transfer-car mechanism inside the furnace at the bottom of the " U ". The main heating section of the furnace consists of a twin chamber with a divided central wall, for the purposes of efficient air circulation, the length of this double section being 35 ft. The furnace wall, roof, and hearth are lined with refractory firebrick backed with graded insulation, while the fixed hearth of the furnace, which supports the coils when they are temporarily static, is capped with heat-resisting steel. Nickel-chromium strip heating elements are arranged on the wall faces and roof, while heavy, inverted V-section heating elements are fitted in the hearth. In order to achieve maximum heat transfer from the elements to the charge, a series of centrifugal fan units is fitted in the roof of the heating chamber.



As a continuation to the double heating chamber, a fully bricked and insulated recuperative chamber assists in achieving the highest possible thermal efficiency, since heat is recuperated by the ingoing coils from the outgoing charge. Along the outgoing section of the recuperative chamber a series of centrifugal fans is fitted to assist in heat transfer from the hot to the cold coils. Finally, at the charge and discharge points are fitted short entrance and exit chambers, with air or atmosphere locks in the form of lifting metal doors. In the exit chamber, high-pressure water sprays are provided for final cooling. To indicate the degree of recuperation obtained, it can be stated that the ingoing coils reach a temperature of approximately 250° C before entering the actual heating chamber, while electricity consumption is around 80 kWh per ton, when heating up to 550° C.

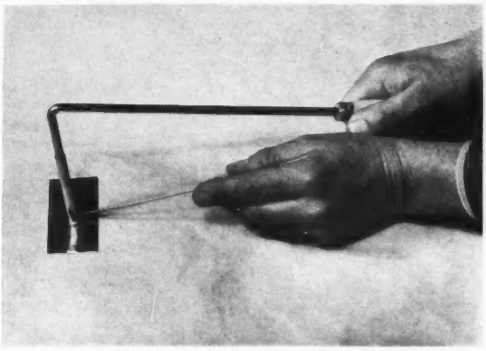
The brass coils being processed weigh approximately 960 lb each and their gauge is of the order of 0·120 or 0·160 in., the strip width being 24½ in. An output of 12 coils per hour is obtained, amounting to 5·15 tons per hour. The furnace is designed for a maximum temperature of 850° C, while the normal working range lies between 550 and 600° C. The rating of 603 kW, arranged in nine independently controlled zones, is evenly distributed over the 3-phase, 50-cycle supply. An additional 150 kW is provided in the bricked section of the ingoing side of the recuperative chamber.

The coils are first received from their preceding rolling operation down an inclined conveyor, the axis of the coils being in the horizontal position. On reaching the manipulator situated at the front of the furnace, the coils are up-ended, so that the axis is vertical, onto a short slat-conveyor section into the entrance chamber, through the atmosphere-lock outer door. By means of a sequence-control mechanism, the coil is passed through the inner door of the lock chamber, and the ingoing beam then lifts the coils from the conveyor to start their journey through the furnace itself. At the bottom end of the furnace, a hydraulically operated transfer car moves the coils across onto the outgoing beam, all these movements being effected automatically. The sequence of operations is then repeated, only in the reverse manner, so that the outgoing beam places the coils onto the conveyor in the discharge chamber. When the exit door opens, the manipulator moves across and extracts the charge, whereupon it is up-ended, so that the axis is once more horizontal, and the coils are then transferred to a gravity conveyor to await subsequent re-rolling. The object of moving the axis from the horizontal to the vertical position when inside the furnace is to permit the air flow induced by the centrifugal fans to pass through the centre of the coils, thus achieving the best possible heat transfer.

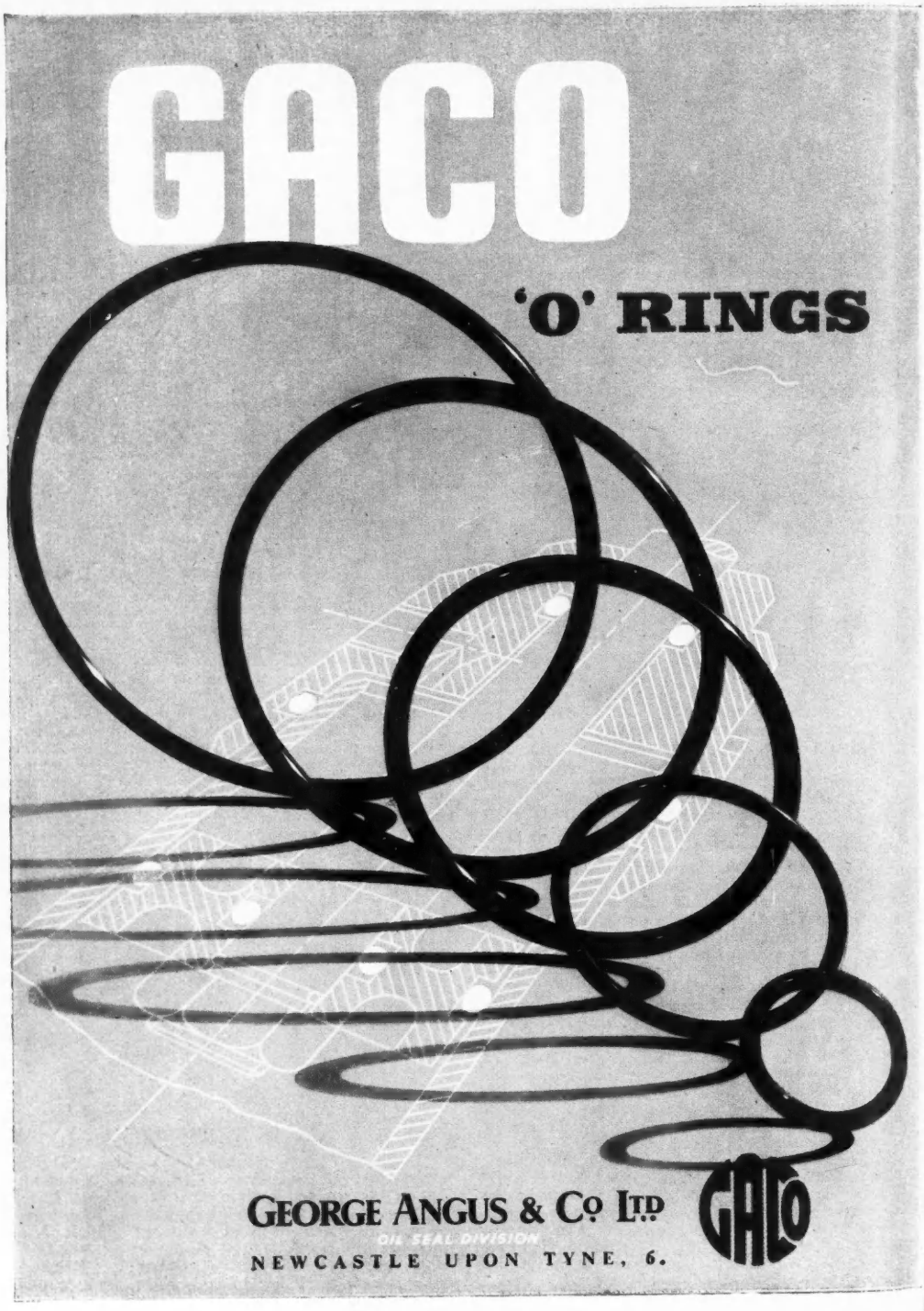
Soldering Tools and Solder for Aluminium Alloys

A soldering tool, which is easily manipulated, light and cheap, and capable of being used for the fluxless soldering of aluminium with any normal solder used for this purpose, has been developed by Tiltman Langley Limited, of Redhill Aerodrome, Surrey. The possibilities of soldering aluminium at 250° C have also been investigated with a solder developed by the company for making corrosion-resistant joints in high-strength aluminium alloys or cold-worked aluminium, without appreciably weakening the alloys being joined.

The equipment used is a hand tool and an electric hot plate for raising the work to the soldering temperature. The technique is to apply the solder and to brush the surface being tinned lightly with a guarded refractory brush on the tool, any of the usual cleaning techniques having been previously applied to the aluminium; no flux is used. The surfaces to be joined after tinning are placed together and a neat fillet of solder produced by sweeping through the molten solder with the refractory brush. Experience has shown that this implement, used manually or mechanically, is more universal in its application than other soldering tools for use on aluminium. It is also less damaging to the surface than other tools. This simple and easily operated equipment can be mechanized for tinning and soldering aluminium, and should have wide application in the electrical industry and for the soldering of small structures.



The Tiltman Langley solder, which has been subjected to salt-spray and humidity tests, has shown good corrosion-resisting properties in aluminium soldered joints. It also provides good mechanical properties. After being raised to a soldering temperature of 250° C for a short time, no appreciable loss of mechanical properties is experienced by the majority of aluminium alloys. A shear strength of 2½ tons per square inch is obtained in such soldered joints.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GAS TURBINES

Sodium Sulphate in Gas Turbines.

By E. L. SIMONS, G. V. BROWNING, and H. A. LIEBHAFSKY. (From *Corrosion, U.S.A.*, Vol. 11, No. 12, December 1955, pp. 17-26, 18 illustrations.)

IN gas turbines burning residual fuels, sodium suplhate formation assumes new importance because ash can deposit directly on the working surfaces. These deposits have physical effects which modify gas flow so as to reduce efficiency; they also can have chemical effects, of which attack of the turbine alloy is the most important. Other distinguishing features of gas-turbine operation are the higher operating temperature (800° C and above) and the use of high-temperature, oxidation-resistant alloys as materials of construction. Although it would scarcely be expected that sodium sulphate itself would attack vigorously a high-temperature alloy, there is always the possibility that some reducing agent (perhaps the alloy itself) will react with this salt to produce a small amount of lower-valent sulphur. Such sulphur might be more reactive than sodium sulphate, and hence a likely source of trouble.

In this paper, the physical effects of sodium sulphate in gas turbines are discussed in terms of sintering and melting, and the chemical effects considered are the various corrosion reactions possible. Although all these reactions are complex, simplified mechanisms for them are proposed, consistent with the experimental results and with general experience. In particular, the violent destruction of a high-temperature alloy by sodium sulphate in large excess is attributed to the triggering of an autocatalytic reaction involving this salt. Even with thin films of sodium sulphate, enhanced oxidation is observed when the atmosphere is alternately reducing and oxidizing. The following mechanism is suggested for this enhancement:—Lower-valent sulphur produced in a reducing environment leads to the formation of a liquid metal/metal sulphide eutectic, which penetrates the alloy. The metal dissolved in this eutectic is more rapidly oxidized by atmospheric oxygen than is the sulphur-free alloy. Sodium sulphate itself appears to be innocuous, provided that all lower-valent sulphur is absent.

Because sodium sulphate will be formed from any sodium compound present in residual fuels, large-scale measures to remove sodium compounds from fuels for combustion are being undertaken. Results so far appear to be promising.

HYDRAULIC ENGINEERING

Generation of High Gas Pressure by Hydraulics.

By J. KENDALL. (From *Jet Propulsion, U.S.A.*, Vol. 25, No. 9, Part I, September 1955, pp. 446-448, 467, 5 illustrations.)

DURING the past several years, rocket engines have grown both in their scope of application and in the volume of units being produced, and have now reached the state of development and application requiring a "limited" production status in several commercial organizations. To-day, rocket engines can be readily designed, tested, and produced in quantities with a high degree of reliability.

Owing to this increase in the use of rocket engines, make-shift handling and test equipment, designed to perform on a limited number of occasions, is no longer economically or operationally feasible. Equipment must be made available to perform reliably and continuously without coaxing or frequent "between-run" overhauls. In order to expedite further the handling and use of rocket engines, the necessary ground equipment must be designed for optimum safety to personnel.

This paper covers the development of a type of portable ground-handling equipment capable of furnishing high-pressure gas in ranges up to 6000 psi, and describes the means by which this high-pressure gas is developed through the utilization of high-pressure variable-volume hydraulic pumps and Greer high-pressure transfer barriers connected to plenum chambers to store the high-pressure gas until required. The transfer barrier acts as a means of separating the high-pressure oil used to develop the high gas pressure from the actual gas itself, in order that, in the development of this pressure, the gas is not contaminated in any way by oil or moisture of any type. By a predetermined cycling arrangement the desired volume and rate of gas desired can be controlled to satisfy the operator's requirements, based upon selection of the capacity of the pump and the number of transfer barriers employed.

HYDROELECTRIC POWER PLANTS

The Stability of "Parallel-Branch" and Differential Surge Tanks.

By O. C. ZIENKIEWICZ. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London.* December 1955, 9 pp., 5 illustrations.)

IN numerous hydroelectric installations construction problems or other considerations necessitate the design of surge tanks with two or more free surfaces interconnected by long galleries. This paper presents a mathematical theory of stability of small oscillations in surge tanks of the type where two water surfaces are present. The name "parallel-branch" surge tank is coined to describe such a system and it is shown that results for orifice and differential surge tanks can be obtained from it.

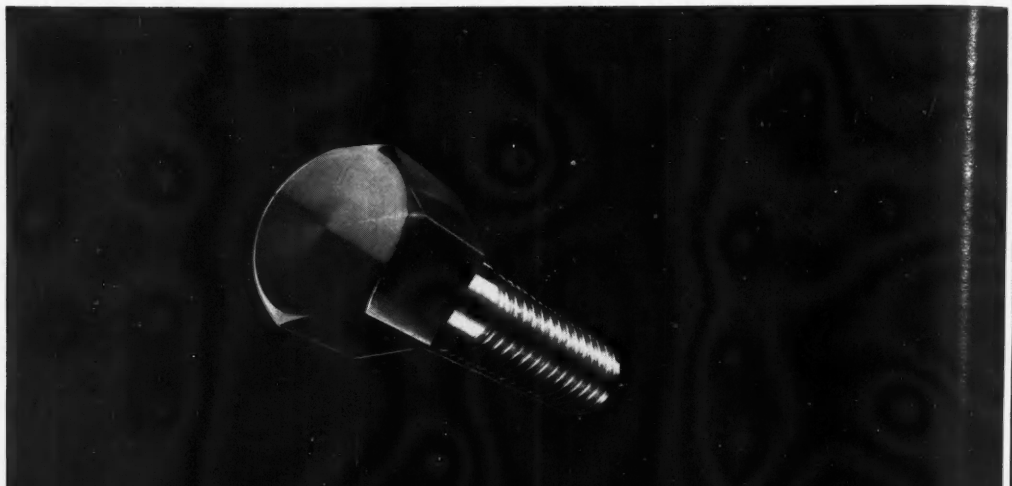
On the assumption of ideal governing and small oscillations of flow and water levels, equations giving the limits of stability are deduced for all cases. It is an easy matter from these to test the stability of any particular design by inserting appropriate numerical values. In general, the results confirm the well-known Thoma formula for the case of a simple surge tank and give results identical with those obtained by Escande for the case of an orifice surge tank. For differential surge tanks, the limits of stability are given in an equation covering the area factors of the riser and the outer chamber, as well as the resistance factors of the main conduit and orifices respectively. Graphs showing this relation between the above quantities indicate :—

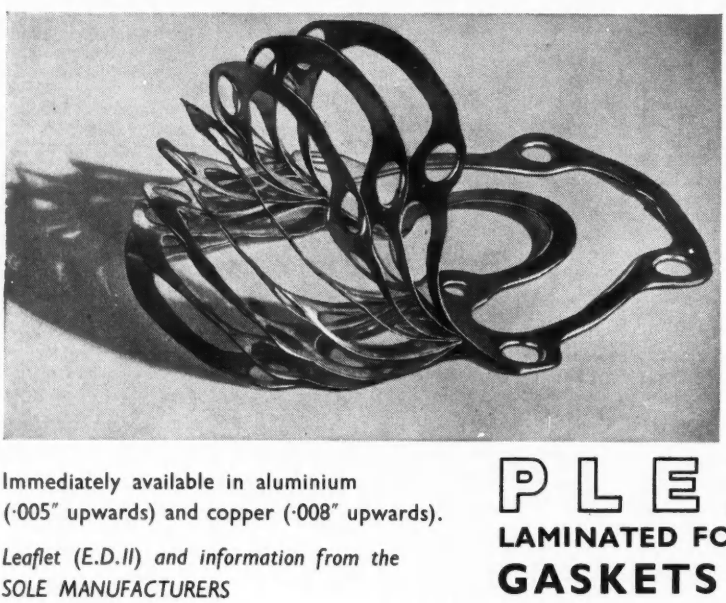
(1) If the combined area of riser and outer chamber is equal to the Thoma area calculated for a simple surge tank, then the system is stable, provided that the resistance factor of the orifice is below a certain limiting value.

(2) When the above combined area is less than the Thoma area, then, in general, small but finite oscillations of the water level will persist. By suitable choice of orifices the amplitudes of these oscillations can be made negligible.

(3) If the resistance factor of the orifices exceeds the previously mentioned limiting value, it is usually not possible for stability to be achieved with riser areas less than a specified value.

Methods of calculating the frequency and amplitude





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of permanent oscillations are presented in the paper. The general case of a true parallel-branch system is best solved numerically, but the results indicate that in all practical cases the phenomenon of finite amplitude oscillations will exist. Attention is drawn, however, to the necessity of considering the period at which instability is possible as, on occasion, this is too short for the assumption of ideal governing to be applicable.

INSULATING MATERIALS

Oven-Heating Tests on Rubber Cable Insulation.

By W. H. COUCH and G. J. CROWDES. (From *Power Apparatus and Systems (AIEE), U.S.A.*, No. 20, October 1955, pp. 930-934, 6 illustrations.)

IN this paper, oven-heating tests on rubber and rubber-like insulation for network cable are described. These tests were made for the purpose of classifying ability to withstand high temperatures for short periods, and are useful as comparisons of actual tests made on completed cables both by oven heating and current loading, offering a simple and easy method of rating insulation.

Insulated conductors were subjected to oven heating for various times up to 30 min and temperatures up to 260° C. Physical characteristics and dielectric breakdown tests were made at each time and temperature combination and detailed examinations carried out. The oven apparatus was carefully designed to provide adequate volume and heating capacity to reduce temperature lag.

There is good qualitative comparison between the oven tests and cable and duct tests made by current loading. As would be expected, the oven tests produce damage at somewhat lower temperatures (approximately 10 to 25° C), since the insulation is heated at a uniform temperature throughout and is without the protection afforded by the jacket.

It is concluded that the oven-heating procedure described provides a quick and convenient method for the classification with respect to the intrinsic high-temperature behaviour of insulation for secondary network cables. This method, when carried out on insulation only, undoubtedly gives temperatures lower than those obtained in service for the same periods. This is due to the fact that the oven temperature is constant, with absence of a temperature gradient, and to the help afforded by the outer coverings normally present. The temperatures indicated can be correlated qualitatively with those obtained with current loading on cable in ducts.

INTERNAL COMBUSTION ENGINES

Some Notes on Carburation and other Fuel-System Problems.

By C. H. FISHER. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, December 13, 1955, 16 pp., 19 illustrations.)

WHILE both vertical down-draught and horizontal side-draught types of carburettor are produced in Great Britain, the majority are of the down-draught variety. There is a distinct trend in body style towards low bonnet-lines, and this has created a demand for shorter down-draught carburettors.

A considerable portion of this paper deals with carburettor icing, which has become a most troublesome factor in fuel-system performance in recent years during conditions of critical atmospheric temperature and humidity. Although throttle ice causes persistent stalling in traffic during warm-up and can be most annoying, main spray ice is, however, more serious, because it can temporarily immobilize the vehicle. Various palliatives are possible, including heating the carburettor or the ingoing air, or using anti-icing additives in the fuel.

At the other end of the temperature scale come vaporizing troubles, causing hot starting difficulties in summer. For these purposes it is necessary to keep the fuel system cool, maintaining a nice balance between sufficient heat to prevent icing in winter, and not enough to cause vaporization in summer.

The need for every possible fuel economy has resulted in the incorporation of automatic economy systems in nearly all carburettors of 30-mm throttle bore and larger. By exploring the mixture range with loops the maximum economy of any particular engine can be determined.

Too much attention is often given to some minor discrepancy in fuel flow between one carburettor and another, and not enough to the discrepancy between the fuel flow induced between one engine and another. These latter variations can be large, as is shown by the relative curves given in the paper.

Automatic chokes provide a controversial subject for discussion and their advantages and disadvantages are evaluated. The author has experimented a good deal with this form of starting, and various suggestions are made for improving the performance of the hot-air type of automatic choke.

WELDING

Initial Characteristics of Chromium-Nickel-Steel Weld Metals.

By J. HEUSCHKEL. (From *The Welding Journal, U.S.A.*, Vol. 34, No. 10, October 1955, pp. 484s-504s, 36 illustrations.)

DIRECT contact with shop and service experiences has demonstrated the hot crack susceptibility of some of the industrially used chromium-nickel-steel metal-arc-deposited weld metals under some conditions of stress. These experiences extend, in varying degrees, to the non-magnetic face-centered-cubic compositions which are austenitic at room temperatures and also to those which contain different amounts of magnetic body-centered cubic ferrite and/or other phases in an austenitic matrix. The sound weld metals in question are ductile at room temperatures, i.e., at that temperature they have substantial capacity to flow and to contract in cross-sectional area when subjected to high tensile stresses. Unfortunately, the high-temperature tensile properties of these weld metals have not been published and the many cracking studies reported in the absence of such data have led to conflicting conclusions.

The investigations described in this article were made to determine the temperature sensitivity of iron-base chromium-nickel-steel metal-arc weld metals under tensile stress. Some compositions and structures exhibit a low order of ductility in the as-deposited condition over a temperature range which is centered at 1800° F. From direct observations it is known that cracking has been experienced for all the welds wherein ductility at 1800° F was low. These include the structures which are fully austenitic at room temperature. The ductility at 1800° F is inversely proportional to the weld-metal strength at this temperature. More specifically, in the as-deposited condition, it is shown to be inversely proportional to the product of the matrix-strengthening and the grain-boundary-weakening components of the composition. The matrix is strengthened at 1800° F by nickel and columbium, and is 19 times as effective as nickel alone. It is weakened by the additions of chromium. The grain boundaries are weakened by the presence of oxides, nitrides, carbides, and silicates, even when the sulphur and phosphorus contents are maintained as low as 0·015%. The stronger matrices require lower impurity contents for the maintenance of a specific ductility level. The stronger matrix compositions, being more strain-sensitive, are susceptible to cracking in the presence of sharp notches under stressed conditions at the higher temperatures.

Solution heat treatment is effective in improving the ductility of the columbium-bearing welds at both normal and high temperatures but, to achieve this advantage, it is necessary to heat the as-deposited weld metal through the brittle-temperature range. Massive, rigid weldments made of compositions which are brittle in the as-deposited conditions may crack under such treatment, unless special precautions are taken.

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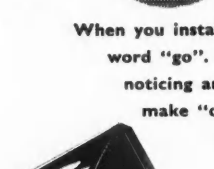

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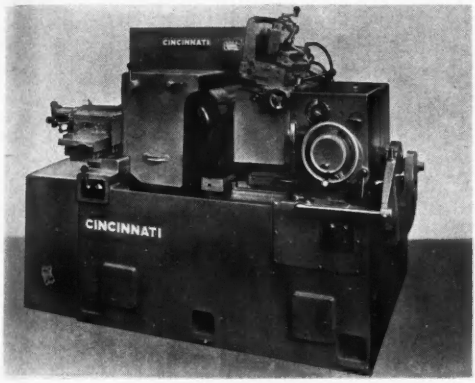
New Materials, Processes, and Equipment

CENTRELESS GRINDING MACHINE

A completely new centreless grinding machine (No. 2), more than 1000 lb heavier than its predecessor, is announced by Cincinnati Milling Machines Ltd., of Birmingham.

Filmatic bearings have been retained for the grinding-wheel spindle. These bearings are self-adjusting for all conditions imposed by the grinding action, are automatically lubricated with filtered oil from a circulating system, and are protected with an electrical pressure switch.



A " lower-slide " unit, mounted on bed-ways at right angles to the grinding-wheel spindle, supports an " upper-slide " unit which carries the regulating or feed wheel. This type of construction simplifies set-ups and sizing adjustments, as the work-rest is mounted on the lower slide, where it can be readily positioned in proper relation to the two wheels. Way-bearing surfaces are well guarded to exclude grit and cutting fluid. To compensate for slight errors in truing and/or set-up, the entire regulating-wheel pile may be swivelled slightly on the bed. In operation, the upper and lower slides are locked together and glide as a unit over anti-friction ways on the bed. Stick-slip, common to plain flat bearings, is virtually eliminated, resulting in accurate sizing adjustments and elimination of the scoring of ways.

The regulating wheel is driven by a built-in 1½-hp motor, through a back-gear combination and a wide V-belt. Regulating-wheel speeds are infinitely variable, within two ranges, from 11 to 320 rpm. Speed changes are accomplished with variable-pitch sheaves, handwheel-selected and indicated on a large tachometer dial at the operator's working position. Both grinding- and regulating-wheel spindle bearings are automatically lubricated with circulating filtered oil from the central hydraulic system. Other bearings within the slide units are lubricated from an oil-shot system.

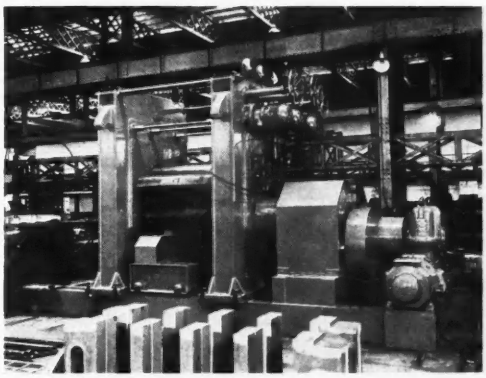
Power-operated profile truing is standard equipment for the grinding wheel and is actuated by a hydraulic motor at one end of the unit. Two external controls are located on the operating side of the bed, one to engage rapid and truing rates and to change the direction of traverse, and the other to change the rate of traverse. The truing unit is designed for formed cylindrical cams. Flat bearing ways on the truing slide are guarded to exclude dust. Regulating-wheel truing is accomplished through a straight handscrew-type unit. However, power-operated truing is available as an extra. Operating controls are then much like the grinding-wheel truing unit. Both units are arranged for diamond truing.

The infeed handwheel for size adjustment and for positioning the slides when setting up the machine is now located on the upper slide at the operator's working position and incorporates all the refinements of a centre-type grinder cross-feed mechanism, with graduated dials of 0·0001 and 0·001 in. For infeed grinding, the operator does not use this handwheel, but rather the infeed lever connected directly to the infeed screw. A 90-deg. arc of this lever, downwards and return, completes a hand infeed cycle.

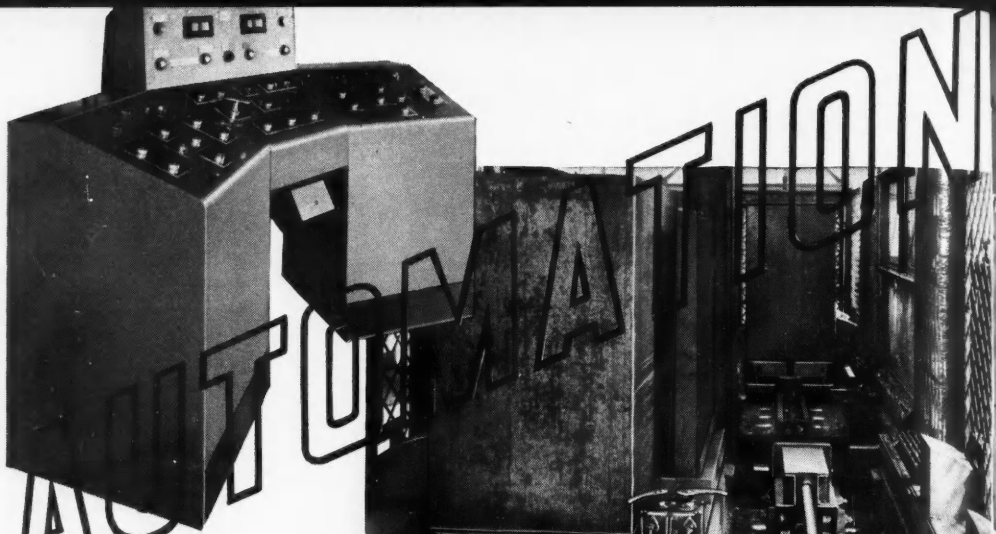
The motor and electrical controls are completely enclosed, and push-buttons are located on the front of the bed at the working position. Electrical controls are contained in a sheet-metal unit at the rear of the machine, equipped with a safety interlock switch and a " load-meter " to show the percentage of available grinding-wheel horse-power being used during the grinding cycle.

DUAL-PURPOSE, HEAVY-DUTY 5-ROLL PLATE-LEVELLING MACHINE

The necessity of being able to deal with plates of considerable range in width and thickness often presents a problem with regard to the selection of a levelling machine capable of dealing with both heavy plates of narrow width and comparatively light plates of much greater width. To overcome this problem Joshua Bigwood & Son Ltd., of Wolverhampton, have recently manufactured a dual-purpose machine equipped with alternative sets of rolls, one set to deal with steel plate up to 10 ft wide × 1⅜ in. thick, and the other up to 5 ft wide × 2 in. thick. The change-over from one set of rolls to the other can be accomplished in approximately four hours and the work can be arranged so that the machine runs for a lengthy period between each change-over.



The machine consists of two fabricated steel housings of unit construction, stress-relieved after welding and carrying the bottom rolls in phosphor-bronze sleeve-type bearings. The adjustable top-roll chocks work in machined slideways in the housings, which also incorporate the roll screwdown drive. The weight of the rolls and chocks is balanced by heavy springs contained in the housings. The screwdown is power-operated by 5-hp geared reduction motors and is fitted with handwheels for fine adjustment. Indicators showing roll positions are fitted. So that roll changing may be facilitated, lifting lugs are incorporated on the housings, the tie bolts are located in slots, and the bearing assemblies permit the rolls to be drawn out without hindrance. A heavy fabricated steel bed, which carries the machine housings, gearbox, and motor drive, is so designed as to accommo-



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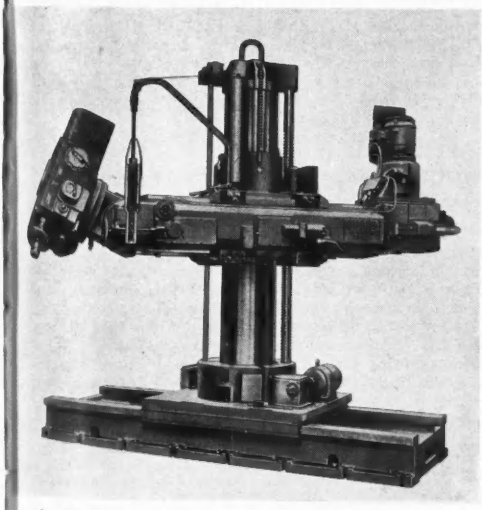
date the outer housing in alternative positions to suit the long or the short rolls.

The drive is by a 65-hp reversing slip-ring motor, through a heavy-duty worm reduction gear to a fabricated gearbox which distributes the drives to the lower rolls. The two sets of rolls are machined from carbon-steel forgings, and their diameters are such as to enable them to withstand, with an ample margin, the stresses set up by the imposed loads and to ensure that there will be no excessive deflection under all working conditions. The drive to the bottom rolls from the gearbox is via splined couplings of such a diameter that the roll may be drawn out of its bearings while the coupling is still in place. To support the rolls during removal and replacement of the outer housing, a movable jack is located on ways between the housings.

To avoid the necessity of uncoupling the lubrication pipes during roll change, thereby inviting the ingress of air and dirt to the system, each housing is fitted with its own central hand-pump grease system. These feed the roll bearings, roll adjusting mechanism, and (in the case of the inner housing system) the gearbox bearings. The gearbox gearing is lubricated by hand and is of the open type, enclosed by sheet-steel guards.

UNIVERSAL RADIAL DRILLING MACHINE

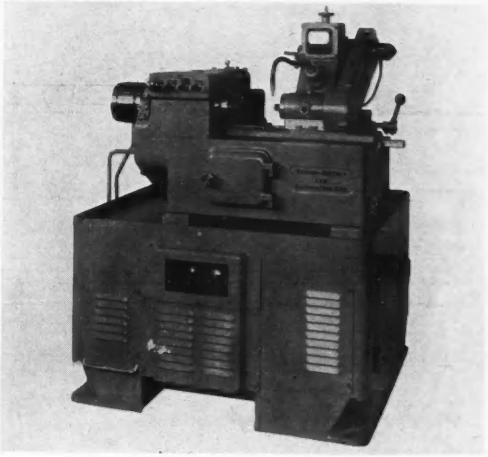
A new, compact universal radial drilling machine, with compound headstock swivelling for conventional, as well as horizontal, angular, and compound angular drilling operations, has recently been developed by the Kaukauna Machine Corporation, of Kaukauna, Wisconsin. The machine is designed for either stationary or portable applications and features lifting bail and spreader-arm supports on the base, resulting in a considerable saving in workpiece handling and set-up time. Furthermore, a preselector type of automatic speed-change mechanism is fitted, while the reduced overall size of the machine, without any reduction in its capacity or working area, enables it to be used in confined spaces.



A comprehensive variety of machine movements permits efficient machining operations on both large and small work. Horizontal drilling operations can be carried out up to a height of 14 ft 6 in., and vertical drilling both upwards and downwards, while angular and compound drilling is possible in any plane. Machining operations on multiple surfaces can be effected with one workpiece set-up, thereby reducing crane-handling time, while tooling requirements are simplified and fixtures frequently eliminated.

HYDRAULIC SEMI-AUTOMATIC THREAD-MILLING MACHINE

A new and versatile 4 × 9 in. semi-automatic thread-milling machine has recently been developed by the Hanson-Whitney Company, a division of the Whitney Chain Company, of Hartford, Connecticut. The new machine, of compact design, is completely hydraulic in operation, including the pump and hydraulic motors for actuating the work head and cutter head; thus, cutter speed and work speed can be balanced and, combined with rapid traverse, optimum cutting conditions for the work involved are produced. Furthermore, spindle speeds are infinitely variable within the normal cutting range to facilitate the machining of unusual alloys. The standard machine is made with an internal or external cutter head and will produce internal or external, straight, or tapered threads up to 4 in. in diameter, 9 in. from the collet nose.



Once set up, the machine is semi-automatic in operation, and all controls are easily accessible. Interchangeable lead cams and cross-feed cams are included in the machine, together with other specific design features, including a tachometer for indicating cutter-head speed and a quick-acting hydraulic collet-closing mechanism, with a hole through the centre for accommodating long shafts. In addition, all hydraulic-pump and coolant-pump equipment, including an extra-large capacity fluid supply tank, is enclosed within the base and arranged for easy maintenance, while the cutter spindle is equipped with taper roller bearings, permitting heavy cuts at high speeds.

MERCURY-SWITCH TYPE CONTACTORS

Featuring very low consumption and quietness of operation, a comprehensive range of mercury-type contactors is announced by John Baggs & Co., of Uppermill, near Oldham, Lancs. Single, double, triple, and multi-pole models are available, with ratings between 2·5 and 100 A, and voltages between 25 and 400/440 V (a.c.) and 6 and 100/125 V (d.c.).

The movement of these contactors is spring-controlled and so arranged that, at the point of maximum operation, the magnetic pull falls substantially to zero, with the result that mechanical shock, which can damage mercury switches, is negligible, while make-and-break is precise and multiple breaking is eliminated. Gravity-controlled contactors can also be supplied.

The shape and location of the armature with respect to the operating magnet is such that the longitudinal pull on it is almost entirely cancelled out, so that the contactor is quiet in operation. The armature is mounted

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your specification puts you apart,
you mustn't be this, you've got to be that;
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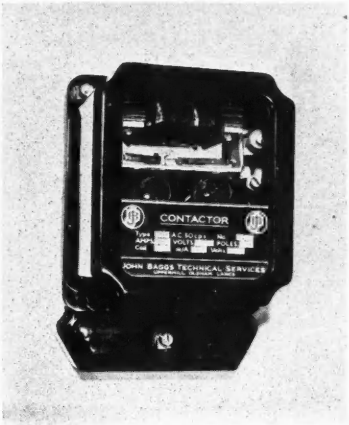
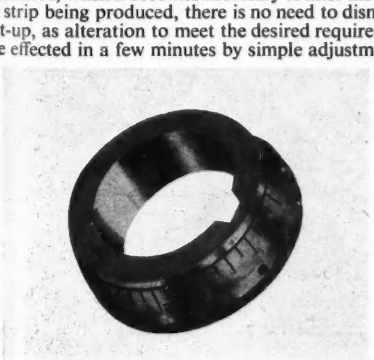
on steel pivots running in special bearings lubricated with silicone grease, which does not vary its viscosity with temperature. Further lubrication is unlikely to be required for many years. Springs are of stainless steel. Self-locking nuts are fitted throughout. Special attention has been paid to the arrangement and location of the switch leads, which, where necessary, are held in their respective positions by suitable rubber grommets. The leads to the switches are insulated with silicone elastomer sleeving which, whilst being more flexible than rubber, does not crack, perish, or change its properties with time or at temperatures between –60° C and + 180° C.



All single- and double-pole contactors and relays up to 50 A can be supplied in moulded cases. These cases are, as illustrated, of the electricity-meter type with a glass front, giving a clear view of the mechanism and having enclosed bottom terminals. An extended terminal cover can be supplied to enclose the connections. Certain of the smallest sizes can be supplied with a moulded cover and an insulated backplate with back or top connections. Any type can be supplied with a metal cover and front or back connections.

GROUND-THREAD MICROMETER SPACING COLLAR

Specially designed for use on slitting and rolling machines producing metal strip, a new ground-thread micrometer spacing collar is announced by Euco Tools, Ltd., of Kingston, Surrey. It is stated that a machine fitted with these collars can now be set up quickly to produce metal strip to limits of 0·0005 in., with consequent freedom from burring, as a result of the exact register which can be obtained between the top and bottom rolls or cutters. Furthermore, when it becomes necessary to alter the width of the strip being produced, there is no need to dismantle the set-up, as alteration to meet the desired requirements can be effected in a few minutes by simple adjustment of the micrometer spacing collars. An additional advantage is the fact that these collars enable a machine to produce non-standard sizes of strip without the need for a completely fresh set-up with spacing collars of special sizes.



Constructed from tool steel, hardened and tempered, the new micrometer spacer consists of an inner collar keyed to suit the machine arbor. The outside diameter of the inner collar is provided with ground threads of micrometer pitch, screwing into an outer collar with internal ground threads of similar pitch. The bevelled outside diameter of the outer collar is calibrated into 50 divisions, so that each equals 0·0005 in., while a complete revolution of the collar equals 0·025 in., A datum line on the inner collar registers with these widely-spaced calibrations, permitting setting to close limits to be made easily and quickly. All mating surfaces are precision-ground, and a socket-type set-screw is provided to enable any desired setting to be retained.

PORTABLE PUMP

Designed to combat flooded floors, standing water on flat roofs, and for quick, emergency use, a lightweight portable pump is announced by Hypro Engineering Inc., of Minneapolis. Equipped with a vacuum switch permitting untended operation and weighing only 26 lb complete with motor, hinged carrying handle, and vacuum switch, the new pump has a capacity of up to 5 U.S. gpm with pressures up to 30 lb. The unit can be easily moved from one spot to another in industrial plants whenever fast water transfer is required, while the special vacuum switch guards against burned-out impellers by stopping the pump motor automatically when the liquid supply runs dry.

Handling either clean or dirty water with a minimum of clogging, this pump will lift water up to 10 ft unprimed or 22 ft primed and has outside threaded ports for standard female garden-hose couplings. The hollow shaft of the pump slips directly on to the shaft of the ¼-hp motor, eliminating the need for a base-plate or coupler.

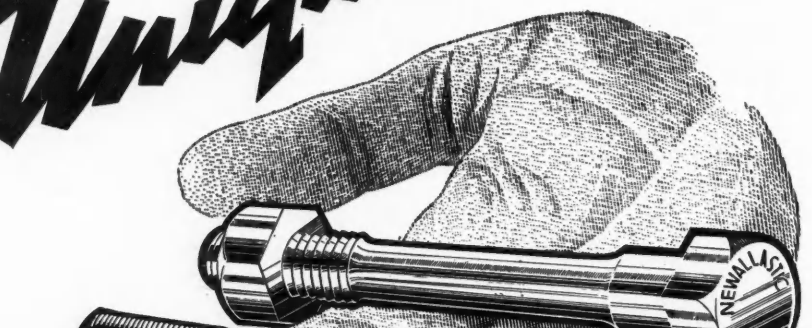
A Simple Ultra-Microtome for Use in Electron Microscopy

(*Concluded from page* 8)

microscope to ensure that, at a particular power dissipation in the heating coil and a particular speed of rotation, sections were cut continuously for about 40 min. After the nickel core had cooled down, the knife was replaced by the pick-up of a displacement meter ; the solenoid *G* (Fig. 2) was removed (but remained connected, so that the electrical circuit was unchanged). For about 40 min the displacement measured by the pick-up was recorded on a recording instrument. About 2 min are required after switching on before the heating coil transmits sufficient heat to the nickel core ; the expansion was only 0·2 μ in the first 2 min. In the following 3 min the core expanded 1·08 μ. The cutting speed being 49 sections per minute, the average thickness of the sections during these 3 min was 73 Å. The instrument, during a period of about 20 min, cut sections of a reasonably reproducible thickness of 80 ± 10 Å. With this instrument, incidentally, it is quite possible to make sections of 50 Å.

An electron-microscope exposure of a section of aluminium made with this ultra-microtome is shown in Fig. 3. In this case, an aluminium rod was shaped so that a small pyramid, about 0·3 mm in height and with a base of 0·3 × 0·3 mm, protruded at one end. The tip of this pyramid was then cut with a diamond knife, the angle between knife and specimen being particularly critical.

Unique



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NEWS OF THE MONTH

PERSONAL

Mr. W. R. Bishop has accepted an invitation to join the Board of J. A. Prestwich Industries Ltd., Northumberland Park, London, N. 17.

Mr. Sam Black has been appointed head of the publicity department of the British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W.C.2.

Mr. G. Brewer has been appointed cast iron and bronze foundry manager, and **Mr. S. Marton, B.Met.** (Sheffield), to a new research post, with Sheepbridge Engineering Ltd., Chesterfield. **Mr. D. Berridge** has been appointed sales manager.

Mr. A. C. Brierley, who is at present in the Export Department of United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10, has been appointed light steel sales manager of Samuel Fox and Co. Ltd., Stocksbridge Works, near Sheffield, in succession to **Mr. J. H. Goodlad.**

Mr. J. E. Bywater has been appointed manager of the Birmingham Research Centre of the Ford Motor Co. Ltd., in succession to **Mr. G. H. Tunna,** who has taken up an appointment at the Dagenham works of the Company.

Sir Ivor Cox has been elected deputy chairman of A.E.I. Overseas Ltd., Crown House, Aldwych, London W.C.2. He will be succeeded as group managing director by **Mr. F. J. E. Tearle,** who has also been elected a director of A.E.I. Ltd.

Mr. R. K. Deane has been appointed production controller of R. B. Pullin & Co. Ltd., Phoenix Works, Great West Road, Brentford, Middlesex. **Mr. H. R. Botting** has been appointed chief buyer.

Mr. G. A. Dickins, B.Sc., A.R.I.C., F.Inst.P., has been appointed technical manager of Mobil Oil Co. Ltd., Caxton House, London, S.W. 1, in succession to **Dr. R. B. Killingsworth, F.Inst.P.,** who has returned to the United States.

Mr. R. Drinkwater has been appointed turbine specialist engineer with Brush Electrical Engineering Co. Ltd., Loughborough, in succession to **Mr. R. D. Taylor,** who is now London branch manager of the company.

Mr. T. R. Hardman has been appointed general manager of Tecalemit Ltd., Plymouth, Devon, and Brentford, Middlesex. Mr. Hardman is also a director of Foamite Ltd., manufacturers of fire fighting equipment, a subsidiary company of Tecalemit Ltd.

Mr. F. W. Halliwell, C.B.E., M.I.Mech.E., M.I.Prod.E., chairman and managing director of Gay's (Hampton) Ltd., has been re-elected President, and **Mr. S. J. Harley, B.Sc., M.I.Mech.E., M.I. Prod.E.,** chairman and managing director of Coventry Gauge & Tool Co. Ltd., has been elected Deputy-President of The Gauge and Tool Makers' Association, Standbrook House, 2/5 Old Bond Street, London, W.1. **Mr. A. L. Dennison, M.I.Prod.E.,** chairman of Birmingham Tool & Gauge Co. Ltd., and **Mr. H. S. Holden, M.I.Prod.E.,** managing director of Brooke Tool Manufacturing Co. Ltd., have been elected vice-presidents, and **Mr. L. E. Van Moppes,** director of L. M. Van Moppes & Sons (Diamond Tools) Ltd., has been elected chairman of the Association. **Mr. G. P. Barrett, M.I.Prod.E.,** director and secretary of Precision Grinding Ltd., and **Mr. T. Ratcliffe, M.I. Prod.E.,** chairman and managing director of Ratcliffe Tool Co. Ltd., have been elected vice-chairmen and **Mr. R. Kirchner, M.I.Mech.E., M.I.Prod.E.,** has been re-elected honorary treasurer of the Association.

Mr. R. Hart Still has been elected to the Board of Bakelite Ltd., 12-18 Grosvenor Gardens, London, S.W.1. **Mr. A. J. Hearn** has been appointed chief accountant, **Mr. A. Lloyd,** production controller, **Mr. R. C. Mountford,** works manager, Ware, **Mr. C. D. Philippe,** sales manager, Thermoplastics Division, **Mr. C. A. Robb,** general works manager, **Mr. A. W. Sherwood,** sales promotion executive, **Mr. P. Smith,** general sales manager, Home Sales, and **Mr. G. J. Taylor,** commercial relations executive.

Mr. E. Heliot has been elected President, and **Mr. A. W. Bell,** vice-president, of the British Association of Machine Tool Merchants, St. Stephen's House, Victoria Embankment, London, S.W.1.

Mr. F. B. Howard-White, M.C., a director of Henry Wiggin & Co. Ltd., has been appointed a Member of the Mond Delegate Board.

Dr. T. P. Hughes, M.A., Ph.D., has been appointed director of the research laboratories at Hinxton Hall, Cambridge, of Tube Investments Ltd., The Adelphi, London, W.C.2. **Dr. F. P. Bowden, F.R.S.,** is the chief research consultant to the company.

Mr. Edward A. Hyde, has been appointed managing director of Wickman Ltd., Banner Lane, Tile Hill, Coventry, in succession to **Mr. George R. Marsh,** who resigned his office, but will remain a director of the company. **Mr. M. V. Hodgson** has been appointed deputy managing director, **Mr. C. F. Watts,** financial controller, and **Mr. H. B. Morris,** secretary of the company.

Mr. T. S. Kilpatrick has relinquished his duties as commercial manager of Distington Engineering Co. Ltd., but remains on the Board of the company. He has taken up appointment as deputy general manager of the Workington Iron and Steel Co. Ltd. **Mr. A. E. Bell** has been appointed general sales manager (Engineering), and **Mr. T. Wintrup** has been appointed sales manager (Engineering).

Mr. J. N. M. Legate, B.Sc., A.M.I.E.E., has been appointed assistant chief engineer, Industrial Control Department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17.

Mr. T. P. Lloyd has been appointed works manager (Services), in succession to **Mr. W. Geary,** who has been assigned for special duties for the general works manager in connection with management studies and statistics at The Appleby-Frodingham Steel Co. Ltd., Scunthorpe. **Mr. W. Jackson** has been appointed works manager (Steel).

Mr. F. E. Mills, until recently sales director and general manager, has been appointed managing director of B.I.P. Engineering Ltd., Streetly, Staffordshire.

Mr. Terence O'Neill has been appointed personal assistant to **Mr. Eric E. Jones,** commercial director of The Solarton Electronic Group Ltd., Thames Ditton, Surrey.

Mr. T. D. Ough, B.Sc., A.M.I.I.A., works manager, has been appointed general works manager of Acheson Colloids Ltd., Plymouth, with overall responsibility for production at all Acheson factories in Europe. He is succeeded by **Mr. H. G. Davis, B.Sc.,** previously deputy works manager at Prince Rock, Plymouth.

Mr. A. G. Peacock, B.Sc., A.R.I.C., A.Inst.P. has been elected chairman of the electrical and electronics section of the Scientific Instrument Manufacturers' Association, 20 Queen Anne Street, London, W.1., in succession to **Mr. P. Goudime, M.A., Mr. R. Y. Parry** and **Mr. L. A. Woodhead** have been elected vice-chairmen.

Mr. G. N. Petty has been appointed Diesel export manager of D. Napier & Son Ltd., The Vale, Acton, London, W.3. **Mr. W. E. Hampton** has been appointed Aviation export manager, and **Commander G. N. Torry, R.N. (Retd.),** has joined the Commercial Division, responsible to **Mr. J. B. Waite,** Aero engine sales manager.

Mr. P. C. Pritchard has been appointed assistant sales manager of George Ellison Ltd., Perry Barr, Birmingham 22 B. He will assist **Mr. G. A. P. Jewiss** in the general supervision of all sales activities and will be in direct control of the internal sales organization.

Mr. J. H. Russell, works director, has been appointed deputy managing director of Hall & Pickles, Ltd., Manchester 1. **Mr. F. R. Robbins,** general sales manager, has been appointed sales director.

Mr. Ananta B. Sarkar, M.Sc.(Calcutta), M.Sc. (London), Grad. Brit.I.R.E., has joined H. J. Leak & Co. Ltd., Brunel Road, London, W.3.

Mr. C. M. Slocombe has been elected to the Board of Samuel Fox and Co. Ltd., Stocksbridge Works, near Sheffield.

Mr. D. A. Strachan, A.I.Min.E., F.I.E.S., M.A.M.E.M.E., has been appointed to the head office of The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, to take responsibility

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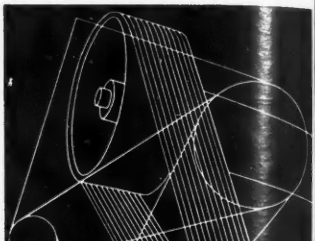

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for Flameproof and Mining Equipment sales. **Mr. S. C. Wells, D.L.C.(Hons.)**, has been appointed to take responsibility for Oil Industry Equipment sales.

Mr. F. Widnall, B.Sc., M.I.E.E., head of the lighting equipment engineering department of British Thomson-Houston Co. Ltd., has been appointed manager of the company's lighting fittings factory at Hereford.

Mr. S. E. Willett has been appointed managing director, and **Mr. S. J. Barnes**, general manager, of Clayton Dewandre Co. Ltd., Titanic Works, Lincoln.

CUTTING FUEL COSTS

For the first time in history, the United Kingdom imported in 1955 more coal than exported—at a cost of £80,000,000 in foreign exchange. If all users of coal could make only a ten per cent. reduction in their consumption, at least 2,000,000 tons would be saved in a year. This would be £14,000,000 in our balance of payments.

There are other urgent reasons for saving fuel. A severe winter or a drop in production from the mines could reduce stocks to a point where cuts to consumers might be inevitable. Further, especially since the 18 per cent. rise in price a few months ago, managements will not need to be reminded of how big a part of their costs coal often absorbs.

In a pamphlet entitled "Fuel Conservation and Productivity", the British Productivity Council sets out the main points which managements need to look at if they are to make sure that their fuel costs are cut to the minimum.

Although it is pointed out that savings can usually be made at many points besides the boiler-house, stress is laid on the need for trained firemen; and details are given of courses available for them. Many of the methods described for saving can be installed with very small capital expenditure. The pamphlet also gives notes on the advisory services available to industry from the National Industrial Fuel Efficiency Service (N.I.F.E.S.) and from the Federation of British Industries; and on the Government Loan Scheme which is designed to help firms to finance the installation of equipment to secure more economical use of fuel.

This pamphlet has been published to coincide with the national campaign for fuel efficiency launched by the Minister of Fuel and Power on 2nd November. The N.I.F.E.S. has itself sent out to 25,000 consumers of over 100 tons of fuel a year a circular describing the notes on maintenance it has prepared and giving details of its boiler-house course. The B.P.C. is supporting the campaign through its Local Productivity Committees; it wishes especially to secure increased appreciation of the large increase in productivity that can be achieved by better use of fuel.

BRITAIN'S NEW JET TRAINER

Britain's first exclusively designed jet trainer—the Student—now being built at the Shoreham factory of F. G. Miles Ltd., is expected to be ready for flight trials early next year. In quantity production this aircraft is expected to cost between £6,500 and £7,250.

The M.100 Student was designed by the Miles brothers in 1953 to Ministry of Supply requirements for a foolproof jet trainer—safe and economical to fly and cheap to produce. Although no Government grants were available, F. G. Miles Ltd. decided to build this prototype at their own expense.

Designed as a single- or twin-engined aircraft with modern flying characteristics, the Student can provide the British and Commonwealth Air Forces with their first exclusively designed basic jet trainer. Since the Student has been designed and built by a small company, it is reasonable to suppose that it can be produced by countries not possessing a highly developed aircraft industry.

The M.100 will be powered by British built Marbore jet engines.

Between 1938 and 1946 the Miles brothers were responsible for the design and manufacture of over 7,000 elementary and high speed training aircraft. Among these were the Magister and Master types in which so many wartime pilots learnt to fly.

F. G. Miles formed a new company in 1950 in a small workshop at Redhill with only four employees. He was joined by his brother George, who as chief designer for Airspeed Ltd. was responsible for the production, design and development of the Ambassador (BEA Elizabethan) and the trainer version of the Vampire. In 1952 the new company moved to Shoreham Airport, specializing in prototype work, tool design and manufacture, aircraft design and structural plastics. Today the company employs over 400 people.

BUSINESS NOTES

Dowty Nucleonics Ltd. have moved to research laboratories and offices at Brockhampton Park, nr. Andoversford, Glos. Tel. No.: Andoversford 391/2.

Fielden Electronics Ltd., Industrial Instrumentation Specialists, Wythenshawe, Manchester, have opened a Midlands office at 18 Wolverhampton Street, Dudley, Worcs. The engineer in charge is Mr. F. Bernard Price. His Tel. No.: Halesowen 1861.

Air Control Installations Ltd., manufacturers of fans of all types, and equipment for air conditioning, air filtration, dust collection and control, fume and vapour extraction, drying, humidifying, pneumatic conveying and vacuum cleaning by central system, have opened a new branch office at 17 Manchester Street, London, W.1. Tel. No.: WELbeck 1306.

Wynn (Valves) Ltd. have moved from Wrexham, Denbighshire, to Granville Street, Birmingham 1. Tel. No.: MIDland 1315. Mr. H. H. Gwillam, technical and sales director of Charles Winn & Co. Ltd., the parent company, has succeeded Mr. G. V. Williams, director and general manager of Wynn (Valves) Ltd., who resigned for personal reasons from the date of the changeover.

Charles Colston Ltd., 3 Mill Street, London W.1., has acquired Tallent (Aycliffe) Ltd., Co. Durham, and Smith-Richards Ltd., High Wycombe. A programme of expansion is in hand at both factories to cater for a big development programme. Mr. J. P. Ford, managing director of Charles Colston Ltd., has been elected chairman of both subsidiary companies.

Sheepbridge Engineering Ltd., Chesterfield, have acquired the whole of the issued share capital of W. E. Bray & Co. Ltd., Feltham, Middlesex, manufacturers of loaders and earth-moving equipment.

Harold Andrews Grinding Co. Ltd., consequent upon becoming a subsidiary of Sheepbridge Engineering Ltd., have changed the name of the company to Harold Andrews Sheepbridge Ltd. The address remains Manor Lane, Halesowen, Worcs.

Tufnol Ltd., Perry Barr, Birmingham 22 B, has opened a new branch office at Ellison House, Woodlands Terrace, Glasgow C.3. Tel. No.: Douglas 5335. Mr. J. D. Bruen, who has represented Tufnol Ltd. in Scotland since 1948, has been appointed manager of the new Tufnol office.

Plessey Research Ltd., another new company within the Plessey Group, has been formed to unify and bring together the control of all research establishments of the Group working in various parts of the country on projects ranging from basic research to component development and application research of various types. Mr. A. G. Clark is chairman and managing director of the new company, whose Board includes Messrs. B. G. W. Attwood, E. J. Earnshaw, Michael Clark and G. C. Gaut.

Beecham Maclean Ltd. announce that their departments previously located at 68 Pall Mall, S.W. 1, and Princes House, Piccadilly, W.1, have moved to Beecham House, Great West Road, Brentford, Middlesex. Tel. No.: EALing 7711.

Moore's (Bournemouth) Ltd. have moved to a new factory at Wallisdown Road, Bournemouth. Tel. No.: Winton 5810/11.

Buck & Hickman Ltd., Watford-by-Pass, have been appointed sole selling agents for the tool and cutter grinder and bench engraving machine manufactured by David Dowling Ltd., Roebuck Road, Hainault, Essex.

Tube Investments Ltd., The Aldelphi, London, W.C.2, have acquired the whole of the issued share capital of Power Centre Co.

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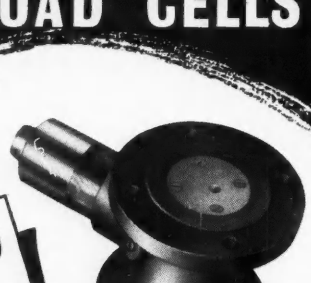

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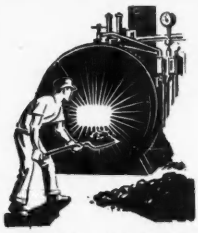

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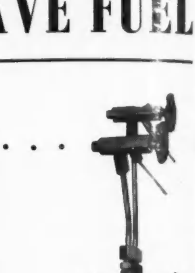

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Installation of an Electronic Computer in Rome. The President of the Italian Republic Signor Giovanni Gronchi inaugurated last month the Ferranti Electronic Digital Computer in the Institute of Applied Mathematics at Rome in the presence of several hundred eminent scientists and Government officials and visitors.

C. C. Wakefield & Co. Ltd., parent company of the Wakefield Group, announce that their principal subsidiary, W. B. Dick & Co. Ltd., has been reconstituted under the name of Wakefield-Dick Industrial Oils Ltd. The new company will also embrace the functions of the former Wakefield-Dick Industrial Lubricants Division of C. C. Wakefield & Co. Ltd. and will operate solely in the United Kingdom ; all export business of the Group being conducted by the Overseas Division of the parent company.

The Board of Directors of Wakefield-Dick Industrial Oils Ltd. consists of L. W. Farrow, C.B.E., chairman, L. M. Broadway, deputy chairman and managing director, W. F. List, assistant managing director, A. J. Sear, J. A. V. Watson, O.B.E., L. G. Packham, R. J. Turner, (general manager, Industrial Lubricants Division), C. F. Dennis, R. F. Baldwin, (general manager, Electrical Division), J. S. Rolph, (general manager, Marine Division), G. H. Thornley and R. Layet. The secretary of the re-named company is L. J. Windridge and the assistant secretary W. C. T. Bowen. The registered office is at 67 Grosvenor Street, London, W.1.

Doulton & Co. Limited announce that while overall control of their business will continue to be exercised by the managing director of the parent company from Head Office at Doulton House, London, S.E.1, their four main production branches will be given separate identities and operate as wholly-owned subsidiaries as from 1st January, 1956.

An existing subsidiary company, Whieldon Sanitary Potteries Ltd. (managing director Mr. R. Mellor, operating from Whieldon Works at Stoke) to be renamed Doulton Sanitary Potteries Ltd. and to control sanitary earthenware, vitreous china and fireclay ware manufactured at the Whieldon Potteries and Dudley Fireclay Works.

A new subsidiary company, Doulton Fine China Ltd. (managing director Mr. J. K. Warrington, operating from Burslem) to control fine tableware, figures and character jugs.

A new subsidiary company, Doulton Industrial Porcelains Ltd. (managing director Mr. R. F. Lindop) to control electrical porcelain, chemical and general stoneware, filters and other industrial ceramics manufactured at Wilnecote Works, Tamworth.

A new subsidiary company, Doulton Vitrified Pipes Ltd. (managing director, Mr. J. P. Medd, operating from Erith) to control drainage goods and conduits manufactured at Erith and Dudley Pipe Works.

Wadkin Ltd., Leicester, woodworking and machine tool manufacturers, have acquired a group of four woodworking machinery manufacturing companies by the purchase, with effect from 2nd January 1956, of the whole of the issued share capital of J. Sagar & Co. Ltd., Canal Works, Halifax, the parent company. The three wholly owned subsidiaries of this company are : Sagar Bursgreen Ltd., Canal Works, Halifax, Burrows Green Ltd., Trawden, Colne, Lancs., and Houghton Engineers Ltd., Houghton-le-Spring, Co. Durham.

Mr. J. B. Bullivant, deputy chairman of Wadkin Ltd., will be appointed chairman of J. Sagar & Co. Ltd. and all its subsidiaries and other directors of Wadkin Ltd. will be appointed to the various Boards. The present chairman of J. Sagar & Co. Ltd., Mr. H. Gordon Sagar, will remain a director, and Mr. John G. Sagar as managing director. The managing directors of the subsidiary companies will also continue in their present capacities. Mr. John G. Sagar will be appointed a director of Wadkin Ltd.

The amalgamation of this group of companies will enable a more complete engineering service to be rendered to the woodworking industries by one organization, and the combination of the extensive manufacturing and engineering facilities will lead to more efficient and more economical large scale production of all the basic types of machines used in woodworking. It will also enable production to be concentrated on the larger high production types of machines, now in increasing demand in the larger woodworking plants, with a consequent shortening of delivery times.

The pooling of the unrivalled technical experience and knowledge represented within these companies, which in the case of J. Sagar & Co. Ltd. extends over a period of eighty years, will also have a far-reaching effect on woodworking machinery design of the future, and provide new possibilities for the development of new and more efficient woodworking techniques.

It is expected that the additional capacity available in Leicester, resulting from this merger, will enable Wadkin Ltd. to continue the development programme of their specialized range of metal cutting machine tools.

Fawcett-Finney Ltd., a new company, has been formed to co-ordinate the manufacturing programmes and to provide integrated sales and service facilities for two old established hydraulic engineering firms, Fawcett, Preston & Co. Ltd. of Bromborough and Finney Presses Ltd. of Birmingham.

The head office of the new company and the Midland Region Sales headquarters is at 27 Berkley Street, Birmingham, and branch offices for London and Southern Region Sales and Northern Region Sales have been established at 60 Buckingham Palace Road, London, S.W.1 and Bromborough, Cheshire, respectively. A Western Region Sales office has been opened at Mayfield Park South, Fishponds, Bristol.

The new company, together with the two manufacturing units is a member of the Metal Industries Group of Companies.

The products of the two manufacturing companies to be handled by Fawcett-Finney Ltd. include : " Fawcett " Hydraulic pumps and valves for water up to 250 hp. Baling presses for all fibres and metals. Industrial and engineering presses. " Finney " Greer-Mercier hydro-pneumatic accumulators. Hydraulic pumps and valves for oil. Hydraulic presses for the plastics and rubber trades. Hydraulic power packs and systems. " Hollman " Vertical and horizontal open-throat presses. " Davis-Standard " extruding machines and ancillary equipment for plastics and rubber with a full range of dies, heads and gear for the wire covering and general plastics extrusion trade. " Baker " automatic moulding machines for the fast curing powders from 25 to 150 tons. " Stubbe " Injection moulding machines.

Both Fawcett, Preston & Co. Ltd. and Finney Presses Ltd. plan to develop existing facilities at Birmingham and Bromborough for the design and production of special purpose plant for the engineering, shipbuilding, plastics, rubber and chemical trades.

SIMA Instrument Centre. A permanent exhibition by member firms is to be opened by the Scientific Instrument Manufacturers' Association at their headquarters at 20 Queen Anne Street, London, W.1, on 9th February, 1956. This decision follows the recent taking over by SIMA of the entire building, necessitated by the rapid growth of the instrument industry. The need for a combined show window in London has been felt for a long time, but lack of space had hitherto prevented the project from being carried out.

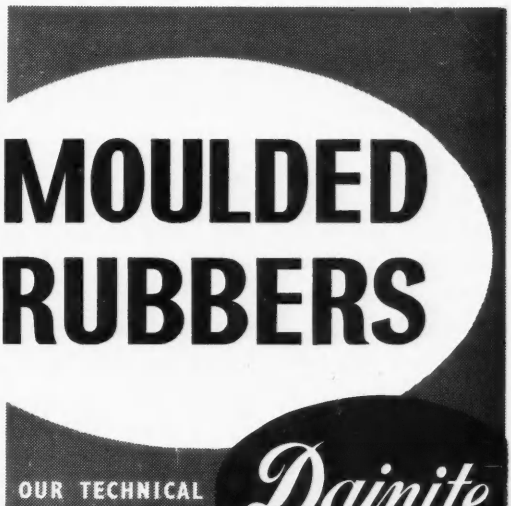
This exhibition will cover an entire floor of SIMA House, which has been completely redecorated in modern style. Since sufficient space is not available to enable all member firms to show their products at the same time, space is allocated by ballot for limited periods, so that the exhibits will constantly change. Arrangements have been made to ensure that a representative cross-section of instruments is always on view.

While the exhibition is not intended to be public, it will be open to anyone interested in using any of the wide variety of instruments manufactured by SIMA members. Overseas visitors especially should find the show useful, since they will be able to inspect there equipment made by firms from all parts of the country. A comprehensive library of members' catalogues is also being established.

Rapid developments in nuclear engineering and automation have led to a greatly increased demand for instruments and control equipment of all types, and the SIMA House Exhibition is intended to serve as a common meeting ground of manufacturers and users.

A further Course on the **" Design of Welded Structures "** is to be held in Cardiff. The Course will commence on the 14th March, 1956, at British Oxygen Gases Ltd., Birchgrove Works, Cardiff, and the lectures will be held on Wednesday and Thursday evenings from 5.0 p.m. to 6.30 p.m. over a period of six weeks.

This Design Course is arranged to assist designers and draughtsmen of welded structures and fabrications, and the lectures will be given by members of Quasi-Arc Technical Staff. On the final evening



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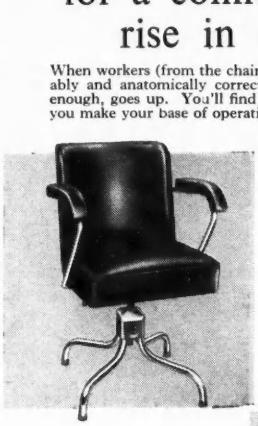

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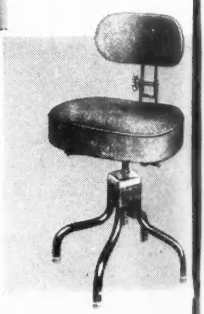

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the Guest Speaker will be Mr. A. V. R. Hooker of Messrs. W. S. Atkins & Partners.

Further details along with the enrolment form can be obtained on application to the Constructional Design Department, Quasi-Arc Limited, Bilston, Staffs.

Transatlantic Britannias may be in Service in 1957. Bristol announce that the *BE 25* turboprop engine has successfully completed its first test run. This powerplant, sixty of which have been ordered by BOAC for later *Britannias*, has also been specified for the projected *Super Britannia*, scheduled for the early 1960s.

Basically an 8,000 hp engine, the *BE 25* is limited to 4,000 hp, an output that can be maintained from sea level to about 20,000 ft. Thus, full power is available for take-off from airfields situated high above sea level—an important consideration in certain parts of the world.

The *BE 25's* constant-power characteristics can be varied according to operators' requirements to give greater power over a lesser altitude range or, alternatively, reduced output to a greater height.

Production of the transatlantic *Britannia 300 L.R.*—the aircraft which will be eventually re-equipped with *BE 25s*—is building up at the Belfast works of Short and Harland. Seven *Mk. 300 L.R.* and nine *Mk. 250 L.R.* aircraft are in various stages of construction and Bristol say that the first *Mk. 300 L.R.* will be ready for non-stop operation during 1957.

The Brush Group Limited announce that they have concluded an agreement with Maybach-Motorenbau G.m.b.H. of Friedrichshafen, Germany, under which Maybach have agreed to grant exclusive rights for the manufacture in the United Kingdom of the Maybach high speed light weight range of MD diesel engines. Provision is made for these engines to be produced by a subsidiary company of The Brush Group Ltd. to be formed for this purpose.

The Maybach MD engine is suitable for use in locomotives with either electric or hydraulic drive, ships and industrial power plant, and has gained a high reputation for its reliability and availability in use on diesel-mechanical locomotives operated by the German State Railways.

CONTRACTS

British Insulated Callender's Cables Ltd. announce that the Sudan Light & Power Co. Ltd. have placed with them an order for approximately seven miles of 33kV aluminium-sheathed Impregnated Pressure cable for the new transmission line from Burri Power Station Khartoum to Omdurman. It is anticipated that installation work, which is to be carried out by the Sudan Light & Power Co. Ltd., with the assistance of British Insulated Callender's Construction Co. Ltd., will commence in the spring or early summer of 1956. The route will include a crossing of the White Nile.

The Tennessee Valley Authority, Chattanooga, has placed a contract for the manufacture and delivery of four transformers with **English Electric Export and Trading Company Limited.** This is the first occasion on which the Authority has accepted an "English Electric" tender.

The transformers are single-phase with three windings for 154/69/13.8 kV. They are of the outdoor, self-cooled type and are rated at 40,000 kVA, 60 cycles.

Other transformer orders received by "English Electric" from the U.S.A. include those for the St. Lawrence Power Project (120MVA, 230kV); City of Seattle (125MVA, 230kV); Chief Joseph Dam (310MVA, 230kV); Bonneville Power Administration (250MVA, 254kV); Folsom Dam, California (80MVA, 230 kV) and Table Rock Dam (121MVA, 161 kV).

British Insulated Callender's Cables Ltd. report the receipt of a substantial order from the Wellington (NZ.) City Corporation for overhead equipment for the extension of trolleybus routes in the eastern suburbs. This order has been obtained in the face of strong foreign competition.

Trolleybuses in Wellington have proved themselves a very popular and successful form of public transport, and it is likely that further extensions to the system will be carried out in the future.

The General Electric Co. Ltd. is to supply the electric traction equipment for thirty of the double-deck trolleybus chassis which have been ordered by the Glasgow Corporation from British United Traction Ltd. These equipments will incorporate the G.E.C. "I.R. Control" system with rheostatic braking.

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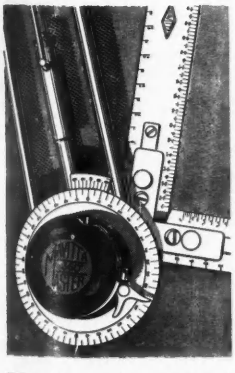

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SITUATIONS VACANT

DRAUGHTSMEN required, who have completed their National Service, for work on the production of power from atomic energy, also for the general development of prototypes and the production and installation of machinery. All this work is for marine installations. Good salaries will be paid to men having the necessary training and experience.

Vacancies are also available for men having experience in the operation of machinery, particularly E.R.A.'s retired from the Royal Navy, and Engineers holding a Certificate of Competency. The work involved would be that of recording trials results for machinery under test. Good salaries will be paid to men having the necessary experience.

A Contributory Pension Scheme is in operation and in suitable circumstances housing accommodation may be available, if required by the individuals appointed.

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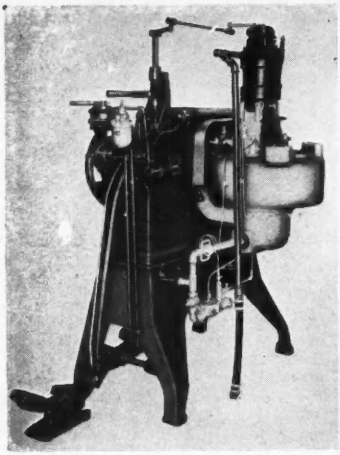

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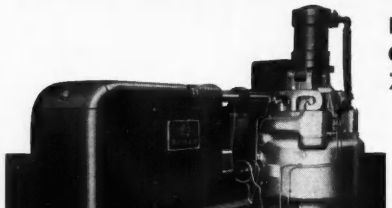

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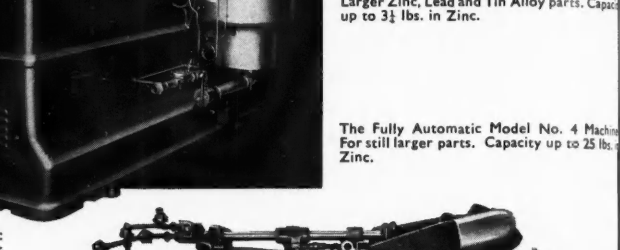

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BOOKS RECEIVED

Errors of Observation and their Treatment. By J. Topping, Ph.D., F.Inst.P. 120 pp., 16 illustrations. Publishers : The Institute of Physics, 47 Belgrave Square, London, S.W.1. Price : 5/-.

All measurements in physics and science generally are inaccurate in some degree, so that what is termed the " accurate " or the " actual " value of a physical quantity cannot be found. However, it seems reasonable to assume that the accurate value exists, and it is of interest to determine the limits between which this value lies. In this connection, it is well to remember that many results given to three or four places of decimals are often in error in the first place and that students have a tendency to suffer from what the author calls " delusions of accuracy ". Indeed, it is only fair to add that, at a higher level, more experienced workers also claim on occasions a degree of accuracy which cannot be justified.

Divided into three main sections, i.e., Errors of Observation, Some Statistical Ideas, and Theory of Errors, and including references, bibliography, and a useful index, this interesting little book (one in the series of Monographs for Students issued by the Institute of Physics), should stimulate in students and others a more reasonable and profound attitude to experimental results.

Modern Petrol Engines. 2nd Edition, 1955. By Arthur W. Judge, A.R.C.S., D.I.C., A.M.I.Mech.E., A.M.I.A.E. 574 pp., 340 illustrations. Publishers : Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price : 56/-.

Dealing mainly with the automobile, aircraft, marine, and stationary high-speed petrol engine and written for the designer, engineer, draughtsman, and student, this second edition of Arthur Judge's well-known book includes an appreciable amount of new material relating to later developments in petrol-engine research and application. In particular, more recent information relating to detonation research, combustion-chamber design, and alternative fuels for petrol engines, including the various fuels for high-output and racing engines, has been given in new chapters on these subjects.

Since the previous edition was compiled, a considerable amount of progress has been evident in engine design and performance, so that appreciably greater power outputs, with lower fuel consumptions, are now obtained from engines of a given cylinder capacity than were hitherto possible. Selected examples of representative or usual types are given, and these afford a good indication of engine trends and progress. In addition, formulae and a correction chart for correcting the results of bench horse-power tests to standard atmospheric pressure, temperature, and humidity conditions have been included, together with information on modern lubricating oils.

Diecasting Die Design. By H. K. Barton and L. C. Barton. 158 pp., 241 illustrations. Publishers : The Machinery Publishing Co. Ltd., National House, West Street, Brighton 1. Price : 17/6.

Despite the varying characteristics of the alloys which can be die-cast and the wide range of the process, the basic principles of die design are of quite general application. A wide range of products, with all their diversities of material, size, weight, form and function, presents to the designer a new and individual problem, which must be solved partly on a basis of accumulated experience and partly by reference to the purely hydrodynamic factors governing the flow of viscous fluids in constricted channels. Nevertheless, even these must be approached empirically, and the design of diecasting dies is still largely a matter of trial and error.

In this admirably produced and illustrated book, one of *Machinery's* Standard Reference Series, the authors have adopted a radically different approach and have sought throughout to analyse and group together the various recurrent features in die construction, and to show their merits and demerits under diverse operating conditions. Primarily, therefore, this is a book for practising diecasters, though in every instance an attempt has been made to show how the design of the diecasting itself influences and reacts with the design of the die from which it will be produced. Accordingly, buyers and designers of diecastings will find, in conjunction with the useful index provided, considerable information on those features in the design of diecastings which increase cost, reduce dimensional accuracy, or detract from the attainment of sound structure and good surface finish.

Knife-Edge Bearings. By P. J. Geary, B.Sc. (Eng.). 69 pp., 19 illustrations. Publishers : British Scientific Instrument Research Association, " Sira ", South Hill, Chislehurst, Kent. Price : 10/6.

This publication (No. 2 in the British Scientific Instrument Research Association's series of bibliographical surveys on instrument parts) covers the period from about 1900 until the present time. The technical introduction reviews the information contained in the literature and constitutes a guide to the section dealing with annotated bibliography, which contains 166 references with more complete digests of texts selected as being of major importance. Topics considered in the technical introduction include the use of knife-edge bearings in balances, weighing machines, and strength-testing apparatus, for the transmission of small movements in mechanical comparators and extensometers, as armature pivots in electromagnetic relays, and as pendulum suspensions. In addition, the loads which knife-edge bearings can carry and the forms and included angles of knife-edges and V-grooves are discussed, together with details of the materials used for knife-edge bearings ; the making, examining, and mounting of knife-edge bearing components ; friction, wear, and impact in knife-edge bearings ; the prevention of corrosion in steel bearings ; and varieties of bearings.

Whilst the arrangement of this new publication is, in general, similar to that used in No. 1 of the series (dealing with " Flexure Drives "), some minor modifications in presentation have been adopted with beneficial results. No. 3 in the series will deal with torsion suspensions and twisted-strip movement-magnifying devices.

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1. System of Atmosphere Control for Direct-Fired Forge and Reheating Furnaces. A new controlled-atmosphere technique, as applied to direct fuel-fired furnaces, is described in an interesting illustrated 12-page brochure. Such a furnace characterizes exceptional progress in furnace design by demonstrating the attainment of scale-free work and improved heating rates and fuel economy, compared with conventional practice. A furnace equipped with this system combines the advantages of increased output per unit of hearth area and less fuel consumption per weight of metal heated—with scale-free heating at temperatures up to 1300° C and higher.

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The pamphlet also describes an electric branding iron, with the same power consumption as the above, designed to provide a clean, rapid method of branding timber, leather, etc. The letters and/or numerals are easily interchangeable into a printing surface of approximately 5 × 1 in.

3. Temperature Detectors, Assemblies, and Accessories. Full descriptions of a complete range of heat-radiation detectors, for continuous temperature measurement up to 5000° F and higher, are contained in a neatly produced and illustrated 24-page catalogue. Advantages of these detectors include the fact that they measure temperature without physical contact, that they respond rapidly to temperature changes, that they operate at variable housing temperatures as high as 350° F without forced cooling, without damage, and with negligible error, that they offer high stability and reproducibility of measurement for precise temperature control, and that they withstand mechanical shock and vibration.

This interesting publication discusses the theory behind heat-radiation measurements of actual surface temperatures and furnace atmospheres, describes the construction of the detectors, and tabulates their characteristics. In addition, it lists complete assemblies for general and specialized applications, together with " exploded " views showing detector components, and details of accessories.

4. Asbestos Textiles. A 10-page brochure, neatly produced and illustrated, describes a comprehensive range of high-quality white and blue asbestos cloth, woven asbestos tapes and linings, asbestos count yarns, asbestos sewing twines, and asbestos sliver rovings. While white asbestos cloth is a standard article of industry, manufactured in a variety of weaves and qualities, blue asbestos cloth combines the valuable characteristics of white asbestos cloth, together with certain special qualities of its own, i.e., greater tensile strength, superior acid resistance, exceptional purity, and unusually high abrasion resistance, while its steel-blue colour is less liable than white to show dust and stains.

5. Air-Operated Pumps, Valves, and Accessories. Details are contained in a well-produced and illustrated 50-page catalogue of a simple, compact pump capable of producing hydraulic pressure from a small volume of compressed air. Once set to give the pressure required, the pump, which is portable and fully automatic in operation, will maintain the pressure indefinitely, without consuming any air. If the balance is disturbed by a leak in the system or in the vessel under test, the pump will automatically start moving, but only sufficiently to maintain the pressure. No less than 34 standard models, single- and double-acting, are available, giving an overall pressure range between 20 and 27,000 psi.

The catalogue includes details of a number of practical layouts, together with descriptions of valves suitable for working pressures between 750 and 50,000 psi, high-pressure couplings, pumps for materials of high viscosity, and special testing equipment.

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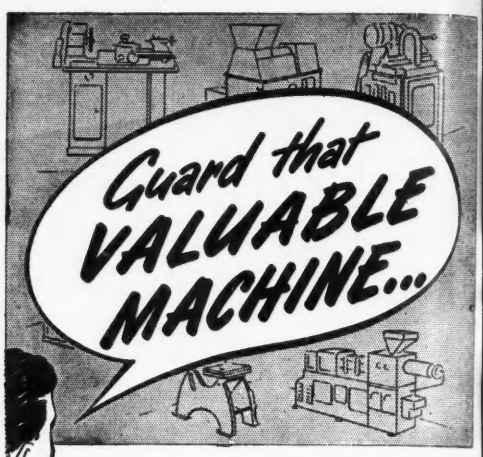

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